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REMINISCENCES AND REFORMS OF THE PATENT LAW.*

BY

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It is appropriate that tonight, in this Institute bearing the name of "Franklin," we discuss two things that probably interested his very catholic mind most: invention and governmental reform—twin pillars in our citadel of modern civilization based upon an industrial democracy.

Reform and research both have their rewards. Thirty-five years ago a youngster of sixteen was evicted from one of our American Colleges because of his advocacy of State rights. Ten years later that same college called him back to receive a Doctorate of Letters for books and articles on the same subject which a change in public opinion had made popular.

Then and there was learned a great lesson. Courage and patience are the essentials of a successful advocacy of reform and time is the great justifier.

Our system of American patent law had its origin in this struggle for States rights. Our revolution and our struggle for freedom from the domination of industrial England was a struggle for American industrial independence. It is a mistaken notion that the closest thing to the hearts of the Colonists was American political liberty. The real struggle was centered upon the right to import machinery from England, to manufacture machinery in the Colonies and the right to invent in the United States. The Colonies demanded

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the right to become integrated manufacturing units instead of mere sources of raw and semi-finished materials for English manufacturing industries.

It was not without cause that Sir Joshua Child, President of the East India Company, complained that: "New England is the most prejudicial plantation to this kingdom," for it was in New England that the growing manufacturing of America was making itself most felt competitively with Britain.

Now across the ocean, England found that she must take legislative steps to curb the industrial life that was growing in the American Colonies, which threatened her manufacturing industries, because America was both the source of supplies for raw materials for England's factories and the market for her manufactured goods.

She saw competing manufacturing rising in Holland and France where her monopoly by British goods was disappearing, for white cloth exports had fallen from 100,000 to 11,000 pieces. Again she saw wool being displaced by East India cotton being imported into the Colonies, which thus developed a weaving industry by establishing cotton mills in New England which gave a dual offense to English manufacturers: first because it reduced their manufacturing of woolen goods, and second because the Colonies had a lighter and cheaper textile material which England could not afford.

So British laws either directly restricted or prohibited certain industries in the Colonies, or discouraged other industries in competing with those of England from which England could make a profit. The first of these laws was enacted in 1699 and they continued to be enacted in increasing numbers until the American Revolution.

When Washington delivered his inaugural address, it was primarily devoted to the encouragement of invention and manufacturing. He was speaking under a constitution whose provision as to patents was proposed and enacted at the convention at Philadelphia without debate and without objection, so apparent was it that it was necessary to the new Union. I believe it was one of the few provisions, if not the only one, that was so enacted by unanimous consent of all political interests. One of the first acts of Alexander Hamil-

ton, as Secretary of the Treasury, was the release of his famous report on the encouragement of manufacturing.

Our patent system is the very core of national prosperity. It is in its essence an expression of our democratic concern for free men conducting independent enterprises. It is not something static, remote from popular will and purely philosophical. To the contrary, it is a warm, human, dynamic and often dramatic system of rewarding industrial courage and inventive ambition. Thus the public gets that which it had never had before.

A patent monopoly is not the monopoly defined by Lord Coke as: "one who, by reason of his exclusive privilege takes something from the public which they had a right to use before the grant of such exclusive privilege," because Coke's monopoly took away something from the public that it had already had. A patent monopoly is a temporary reward to a man for giving to the public something it did not have. Perhaps this statement is no better illustrated than by the story of the Wright Brothers' invention.

My first recollection of patent work was in connection with the preparation of the Wright application on a flying machine. Wilbur and Orville Wright set out deliberately to solve the problem of flight. They read all existing literature and records of failures of others. They then discarded what was already in the public domain and by pure reasoning, confirmed by experiment, made their contribution to the public.

One day after their application for a patent had been repeatedly rejected on the ground that no patent would be granted on a flying machine because none had ever flown, my father, who was prosecuting this application for Wilbur and Orville Wright, called them in and said: "Well, gentlemen, I regret to tell you that it is going to be impossible for you to get a patent. The Patent Office requires that you prove that you can fly your machine."

Wilbur Wright, who was noted for his telegraphic brevity of speech, replied: "Not difficult, we have flown regularly for a year."

In this simple and matter of fact way he announced their great achievement which he did not think sufficiently extra-

ordinary to tell his lawyer, and with his British genius for understatement, he assumed that no one would be interested.

At the argument of the case of Wright Brothers *v.* Curtis in the United States Court of Appeals in New York, Judge LaComb presided.

Judge LaComb had an odd and disconcerting habit of removing his nose glasses by wrinkling his nose. He would keep it up until the glasses finally were dislodged. Counsel for Curtis were apparently much distressed at the extraordinary faces the learned Justice was making in his effort to get rid of his eyeglasses. The Curtis lawyer, a distinguished member of the Bar, appropriately named "Bull," evidently thought there was something wrong with his argument because every time Judge LaComb would start to wrinkle his nose, he would shift his ground of attack.

I wrote a book once on the subject of invention which was mainly interesting because Judge Denison wrote the introduction. Many of you may recall that Judge Denison in his long experience on the Bench became one of our leading authorities on this interesting subject. He was equally noted for his dry humor so that I think possibly a portion of his introduction might be interesting to quote.

> Of what is, and what is not, patentable invention, the courts must finally judge. It cannot be reduced to stated rules, from among which the puzzled judge may select the most appealing one as a safe anchorage. Ever since the Supreme Court, exploring the statute, first discovered that a machine, to be patentable, must be more than new and more than useful, the analytical chemists of this intellectual art have been trying to isolate that "subtle something" which serves as the catalyst whereby skill becomes genius—and with indifferent success. Though many instances seem (to defeated counsel) to justify the famous test—said to have been first stated by Mr. Causten Browne—"If it is so simple that the judge can understand it, then it is not invention," yet this test can hardly be recommended for general use. In the judicial endeavors to this end, judges constantly, even the most eminent and even in the Supreme Court, have labored to state a formula, and have devised one quite satisfactory for the case at hand; just as constantly, the next case, even before the same judge, has proved refractory to that test. The reason why the problem is not amenable to fixed standards has been most happily stated by Judge Learned Hand, in saying that efficient comparisons cannot be made in a realm "where there are no absolutes."

Not so long ago I was arguing a case in opposition to Judge Denison. I had occasion to cite against him an apt case in which we had been co-counsel.

Afterwards, Judge Denison arose and addressed the Court saying that it was not a very good case for as soon as he came into it we lost it, and as soon as he went out, we won it—and therefore, it was not his case so it should not be cited against him.

Reforming the patent law is perennially attractive. Its wastes, its inconsistencies, its injustice and its extravagance at one time fascinated me but each and every sad experience with its reform have tempered the enthusiasm of my youth. Perhaps the following story illustrates this experience.

A good many years ago when President Coolidge was in the White House, an article for one of our national magazines, about the crying need for reforms in the Patent Office, was written. President Coolidge read the article, approved its contents and ordered the Commissioner of Patents to clean his official house.

This he did by appointing a Committee of five Ex-Commissioners of Patents. They met in solemn conclave; each agreed only with the bad suggestions of the others, fearing that if he agreed with their good suggestions some advantage might be gained by the other Ex-Commissioners. As a consequence, the patent system was reformed and it was five times as bad as it was before I started my campaign.

Seriously, the long years of bureaucratic control of the Patent Office and the many more years of the operation of our aging judicial system has resulted in putting patents in a straight jacket. We have lost sight of the original purpose of having patents as rewards for inventors—instead of making their rewards for skilfull lawyers.

The contest between the Courts and the Patent Office on invention is one of the crying shames of our patent system. One branch of the Government, the Patent Office, after a consideration by experts, grants a patent saying that it covers an invention. Often times substantial investments in machinery, plant and capital are made in reliance on this judgment of the Patent Office.

Then in due season when the patent is tested in the Courts, it can be defeated by a Federal Judge who is a layman without technical brains, without serious regard for the Patent Office judgment; he can, if in his opinion, without any factual sup-

port, he does not believe that the patent represents invention, invalidate it. It would seem to be common sense that one branch of the Government should be selected to determine this issue before serious personal and economic damage has been done, and when the question of invention was once settled by one branch of the Government, then it should be final.

Of course, this does not preclude the introduction before the Courts of proof of prior invention by others not before the Patent Office, but it would stop the epidemic that is spreading among Federal Judges of substituting their own largely unsupported lay opinions as to what is or what is not invention rather than confining their judgments to the facts and the law. That indeed was the original conception of the functioning of a Federal Court with reference to the American Patent System.

Can this positive mandate of the Constitution that discoveries are to be protected "to promote the progress of science and the useful arts" be said to be fulfilled when we erect a system of first having the patents granted by the Patent Office because they cover inventions, and then have the courts, in large measure, after the public has made its investment, decide to the contrary? Are we promoting the progress of science by such a system? Are we promoting the progress of the useful arts, that is, the work of the research man, the engineer, the inventor and the manufacturers, and the enjoyment of their labors by the public?

There is only one excuse for enacting a statute to protect inventions. That excuse is the public welfare. This is a manufacturing nation. Its urge toward manufacturing was one of the principal reasons for colonial expansion. Its revolt from the intellectual birth control of its ideas and of its inventions was one of the principal main-springs of its resistance to the non-resident management and control by the British Parliament of our industrial and inventive life.

In the light of this background, it is hardly reasonable to suppose that the framers of this Constitutional provision visualized a Governmental system of protecting inventions by which we first solemnly tell a man that he is an inventor by one branch of the Government, and later equally solemnly,

after having changed his position to his own detriment, tell him by another branch of the Government that he is not. In private affairs, if the Government were not a private party, the rule of equitable estoppel, based upon the rules of fair play, would immediately apply. If an individual would take the position that a mechanism is an invention and induce another to change his position upon that representation, and to make an investment as a consequence, he would never be heard in a court of equity of the United States to deny what he had said.

Not so long ago I had an interesting experience in this field. I was trying a case before a distinguished Federal Judge of quite mature years who was one of those unusual individuals who had never worn eyeglasses. He had never had a case involving eyeglasses or optics. He was not an engineer or scientist. When our trial opened he said that his mind was entirely virgin on the subject. Our patent had received world wide recognition. It had been the basis of unusual commercial success of some sixteen million dollars of eyeglasses in a few years of sales. It had been tested by interference with one of the great optical companies in the Patent Office and the same prior publications and prior patents had been considered and discarded by the Patent Office that were pleaded before this Judge.

But in five minutes after he looked at the patent, he solemnly announced that it did not represent invention. From that position, without the slightest factual foundation, he refused to budge. Such is the evil that arises from permitting one with great arbitrary power to destroy an industry by a whim. I have seen this happen not once but many times.

There is much to be said against sustaining some types of patents. Mr. Justice Clarke, when he was sitting on the District Bench at Cleveland, Ohio, made a very wise observation in a patent suit. He said: "It looks to me like the plaintiff here has set out to invent a patent rather than to patent an invention." A large percentage of the failures to sustain patents is due to just this cause. Laboratories and experimental departments set out to create what they call "patent situations" and to then adorn the results of their synthetic

efforts with bright red seals and pretty blue ribbons. Such efforts are nearly always fatal.

The Courts have a very important function in passing upon patents because they represent the public interest. They are the guardians who must see to it that no invention is allowed to stand which has already been made by another. The recent decision of the Supreme Court of the United States involving the Smith Incubator patent furnishes a good case in point. This patent had been sustained by the Supreme Court of the United States in 1935—two years later we presented to the Court the proof of a prior use many years before by a man named Hastings in Oklahoma. His efforts had been commercially unsuccessful but they were a perfect practice of the Smith method of incubation. Again Mr. Justice Stone wrote the opinion concluding that the patent was invalid with these classic words: "The disclosures made in the Hastings brief (in the Patent Office) were so complete that they might well have been used in support of the Smith claim. Pressed to their conclusion, they would have warranted award of the patent later granted to Smith."

Hastings had actually filed his application for a patent in the Patent Office prior to Smith. The Patent Office rejected his application on the ground of lack of invention. He was too impoverished to appeal so his application became abandoned. Several years later Smith filed his application and, better equipped financially, secured his patent. For nearly seventeen years Smith enjoyed tremendous rewards until his patent met disaster upon the proof of the Hastings prior use.

When an attempt was made, based upon these Supreme Court decisions, to revive the Hastings application and get him his patent, as he had been formally held to be the first and true inventor by the United States Supreme Court, the Patent Office arbitrarily refused to correct its own error on the ground that his poverty was no excuse for failure to appeal, and their original error stood despite the decision of the highest Court of the land. There is something oddly lacking in justice in situations of this character.

Trial counsel have odd experiences with Courts in getting them to understand what seem simple constructions. I was counsel once for the Goodyear Tire and Rubber Company

in the trial of a case against another rubber company for the use of a collapsible core for making of rubber tires. The defendant claimed that the same principles of the patent in suit were shown in collapsible barrel heads. After four days of trial, the learned District Judge beckoned me to the Bench, as apparently I was the youngest and, therefore, the least offensive counsel, and whispered a query to me in great distress: "Tell me, my friend, what is a barrel head?" and the question was asked with the utmost sincerity and seriousness.

In another case we were trying in the far West, after days of testimony about certain pulleys used to drive machinery, the District Judge had his hand upon one of the aluminum pulleys and while he was holding it in his hand, he asked counsel: "I am still puzzled, what is a pulley?"

In a case in a nearby jurisdiction, we were defending against a patent on a side loading hearse. The theory of the invention was that it was more convenient to load the hearse from the side than from the end. In the midst of the opening argument, the District Judge asked me: "What difference does it make to the corpse whether he is loaded into the hearse from the side or end of the hearse?" To which I replied: "If the Court please, I have never been a pallbearer, an undertaker or a corpse, so I am unable to answer the Court's question." The Judge finally decided the case but he was still wistfully curious as to the effect of this invention upon the feelings of the corpse.

Arguing cases in the Supreme Court of the United States on patents is always a very difficult task because of the extremely limited time allotted by the Court. During the precious hour, the questions of such Justices must be answered and complicated mechanism and issues must be explained. Once I was arguing a case when Mr. Chief Justice Taft was presiding Justice. The subject was an automobile shock-absorber that involved a very intricate set of physical principles. The only possible hope of presenting the case to the Court was to present the complete story, and in order to do so, I talked rapidly, slurring the last syllables of each word in order to compress as many words as I could into the hour.

After about fifteen minutes Judge Taft held up his hand to stop me, just like a traffic cop. He went off into one of his

hysterical chuckles and when he finally recovered his composure, he said: "Mr. Toulmin, if you will put back the last syllables on your words, I will give you an extra ten minutes."

Upon my return from France after the World War, my first case to argue was in the Supreme Court of the United States. Two years of war is poor preparation for that sort of an ordeal. I was extremely anxious and extremely nervous.

The defendant was one of the department stores of this city well known to all of you. The case involved an item of merchandise that had been the subject of complicated litigation. In the midst of the argument, Mr. Chief Justice White motioned me to stop the argument. I was sure that I had made some dreadful mistake.

The Court was in a deadly silence; the audience was in a hush expecting the execution of the young counsel. The Chief Justice beckoned to a page. I thought he was sending for the Marshall of the Court to evict me. In a few moments the page returned with an enormous glass of milk which the Chief Justice, with his eight Associate Justices silently looking on, solemnly drank to the last drop. I have never liked milk ever since that time, for the Chief Justice deducted five minutes of my time for his drink.

The art of cross examination is the real art of a lawyer. Skilfully handled it is a potent weapon for justice. One of the greatest factors in a skilfull cross examination is the handling of the witness as to his own physical movements.

I recall a case in which I was confronted with a blustering, able and adroit executive who was possessed of complete information which would make or break my case. He was the only one who could give the complete story. On his cross examination I must depend for success.

In the preliminary questions I found that he was a skilfull antagonist. He sat his chair with the air of a king and he answered questions with shrewdness and assurance. The case involved many exhibits, so I resorted to the device of making him get out of his chair, cross the Court Room and examine the exhibits while I stood by. Then I would ask him several questions and then make him go back to his chair and ask him questions again. By repeating this process over a period of several hours of making him walk back and forth,

he was finally worn down. His assurance, his pride, his imperiousness and his adroitness all went out the window. When he became a simple fellow I asked him one final question: "Why did you take the plaintiff's property?" and he answered wearily "we could not sell our goods without it."

Cross examination has an odd way of backfiring. We were defending a conspiracy suit in one of the southern states. The President of our client was on the witness stand. He had formerly been the General Manager of the plaintiff. He was asked by plaintiff's counsel: "Isn't it true that when you were General Manager of our company you went out at night into competitors' plants secretly without the knowledge of the owners of the plants to get their information as to their secret processes?" Answer: "Yes."

On redirect examination there was nothing to do except explore this question, so I asked him: "How did you happen to go into these plants at night?" He replied: "Because the counsel who just asked me the question on cross examination and the President of our company both told me that if I did not go I would be fired." That was the end of their civil conspiracy case.

The late James W. See, one of the greatest of the patent expert witnesses, was a great genius on the witness stand. When he was confronted with a difficult question he did not want to answer, he would say: "I do not understand the question," and then when counsel would bear down upon him with the question: "What part don't you understand?", he would smilingly answer: "All of it."

There is really nothing you can do with a man like that.

Trials are held in queer places. One of our most interesting cases was a suit against one of the companies operating a New York subway system. After the trial had progressed for some ten days, the defendant halted all traffic on one of the subway lines and ran a special skeleton train while the Judge with stenographer and Bailiff held solemn Court while riding the rails. I believe this was the first time that a Federal Court was ever held while in transit at forty miles per hour under ground.

Ultimately we won the case but the Court had to suspend the injunction for eighteen months to permit the railroad to

change its construction or otherwise a substantial portion of New York traffic would have been immobilized.

Lawyers have strange experiences in Federal Courts with the personalities of the Judges. I once argued a case involving many millions of dollars before a Court of Appeals in the United States where the Chief Justice was so blind that he could not see more than a few feet beyond the Bench, and one of his colleagues on the Bench was so drunk that he spent all of his time in either apologizing to counsel for his condition or trying to rescue the silk gown which was continually falling off. The Chief Justice continually asked questions without permitting counsel to say a word, and when his associates would attempt to ask a question, he would severely reprimand them with the remark: "Why don't you let counsel do the talking?"

This interesting old gentleman had his home in a nearby state, so all week long while holding Court, he wrote himself letters which he opened when he returned home on weekends to the village where he resided. Then again he solemnly dictated replies to his city address.

Among the most noted of the patent judges of our time was the late Judge Westenhaver. I tried many cases before him. It was a joy to do so because of his superb intellect and his marked capacity for eliminating the tinsel and froth of a case from the facts that controlled it. Patent lawyers as a class are great theorists in trials. They build tremendous structures of testimony in the form of window dressing which usually fools no one but themselves.

In one very extended trial where a great agricultural implement company was the plaintiff and I was representing another company as defendant, the plainfiff introduced more than $10,000 worth of charts and models as a part of its prima facie case. The great Court Room at Cleveland was literally filled with these evidences of the industry of counsel and experts. Judge Westenhaver looked over the sea of exhibits and then remarked: "I hope counsel for the plaintiff have enjoyed themselves in placing these exhibits before the Court. So that you may not be misled, this Court is not fooled one bit and will pay no attention whatsoever to these things which

have nothing to do with the case," and with that the plaintiff's case collapsed.

Judges are unexpected in their quaint decisions.

The highwater mark of judicial skill in the decision of patent cases came in a case we tried recently. After three weeks of a very carefully presented case by both sides, the learned District Judge solemnly declared that the patents in suit were valid because they anticipated the prior art.

The present urge to reform the patent law centers about a single Court of Patent Appeals in the place of using Courts of Patent Appeals located in each Circuit throughout the United States.

The proposal to have a single Court of Appeals at Washington has appealed to the orderly sense of engineers, many of whom have enthusiastically adopted it without really knowing what it means.

This is a question essentially for the protection of the individual and particularly of the smaller manufacturing company. It again is a question of States rights or the right of a man to have his cause decided in his own home state and his home Circuit.

We fought England over the proposition of having our legal questions finally decided in London more than 3,000 miles from the Colony but we are proposing to concentrate the settlement of our patent disputes some 3,000 miles away from the homes of our citizens whose interests are involved Nothing could be more disastrous or more expensive than to have a single Court of Patent Appeals at Washington. It would violate all the principles of a democratic Government because we would be taking people to the law instead of taking the law to the people.

The trial of patent cases should never be undertaken unless counsel are people of great determination and clients are of substantial means. Sometimes there are long hard rows to be hoed before justice makes a visit.

In one case on which we spent twelve long years trying to get justice for a defendant, every interlocutory and every final decision was against us. Upon the final hearing in the Court of Appeals at the end of twelve years, after the patent had been sustained by the Court and the case was on an

accounting with a great judgment against our client, we knew then the loneliness that comes to all rear guard commanders. There was not a kind word said by the Court and there were many hard ones said from the Bench. There was only one answer to make to all of the Court's attacks—"We know we are right."

Nine months later the Court reversed all of the lower Courts, substantially reversing itself as well, awarding only a dollar's damages. The only decision that counts is the last decision.

Such are the thrilling fruits of victory gained only by determination, faith and trust in a just cause.

ON THE INTERNAL RESISTANCE OF SOLID BODIES.

BY

SEIICHI HIGUCHI.[1]

ABSTRACT.

Using new types of cantilever test-pieces made of 7 different metals and taking necessary precautions in carrying out the present experiment, the natural oscillations of these metals are carefully examined. Based on the results of these experiments, the law of the internal resistance of solids is studied.

The main conclusions arrived at are as follows: In the state of small stress, the law of viscous resistance may be recognized as being true, as was already expected by the present writer from his previous investigations.

§1. INTRODUCTION.

In this paper, I first obtained experimentally the logarithmic decrement, and amplitude diagram corresponding to the natural oscillations of cantilevers made of 7 different materials, and secondly, based on the results of the above experiments, the law of the internal resistance of solids was studied.

As is commonly known, the results of much research relating to this subject and its application have for years been published by various investigators.[2] However, in this connection, it seems to me to be regretted that only few attempts have hitherto been made to investigate this problem experimentally with the following most necessary precautions:

(1) The methods of clamping the test-piece adopted widely by many previous investigators seem to me to be somewhat unsuitable.

Excessively tight clamping of the test-piece causes undoubtedly serious local stresses at the position of clamping, and, if the clamping is too loose, the condition also would be

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[2] W. Voigt, *Ann. d. Physik u. Chemi*, **47** (1892); K. Honda and S. Konno, *Phil. Mag.*, **42** (1921); S. L. Quimbey, *Phys. Rev.*, **25** (1925); A. L. Kimball and D. E. Lovell, *Phys. Rev.*, **30** (1927); K. Sezawa and K. Kubo, *Rep. Aeron. Res. Inst.*, VII (1932); C. Zener, *Phys. Rev.*, **52** (1937), etc.

For a synthetical report of this subject, see my paper, *Sci. Rep. Tôhoku Imp. Univ.*, XXVI (1937), 236.

incorrect. Furthermore we consider that the usual tapering test-pieces used in these experiments are unsuitable because there are no means to specify the length of such test-pieces accurately.

(2) For the purpose of exciting the oscillation of a test-piece, electro-magnetic mechanisms are frequently employed. However, in the cases in which the material of the test-piece or its attached load is a feromagnetic substance, the methods just mentioned can no longer be applicable, on account of the magnetic influence upon the motion of the test-piece in question.

(3) Though it is very important to obtain and measure the amplitudes of oscillation as minutely as possible, yet there are few among the previous investigators of this subject, who have thoroughly studied these phenomena when occurring in a range of small amplitude. Accordingly, we have been obliged usually to exterpolate the curve in the logarithmic decrement, and amplitude diagram which is constructed mostly by the experimental points lying merely on the position of large amplitude to the range of the small one.

The importance of these precautions will fully be explained later on.

In our experiment, we used a newly designed test-piece which fulfils approximately the clamped condition of a cantilever, and we used also a mechanism of entirely mechanical nature in exciting the motion of the test-piece.

Seven test-pieces of equal dimensions, made respectively of annealed brass, Cu, Al, Duralumin, steel, Ag and Zn were used.[3] Using the data obtained by the experiment, the damping natures of the several vibrating test-pieces are shown, and then the logarithmic decrement and amplitude diagrams are finally constructed. Regarding this diagram a detailed explanatlon is given on the following points.

[3] Brass { Cu 58.64, Zn 37.73, Sn 0.97, Pb 2.39 }
Duralumin { Cu 3.77, Mg 0.53, Mn 0.38, Si 0.39, Fe 0.38 }
Mild steel { C 0.20, Si 0.02, Mn 0.51, P 0.02, S 0.03 }

(1) The general features of the logarithmic decrement and amplitude diagram which are obtained from the lateral oscillation of the cantilever experimented with, are considered.

(2) In the case when the existence of a law of solid viscosity may be recognized as being probably true, calculations of the coefficient of the viscosity of a solid, and, at the same time, discussions of other allied problems are needed.

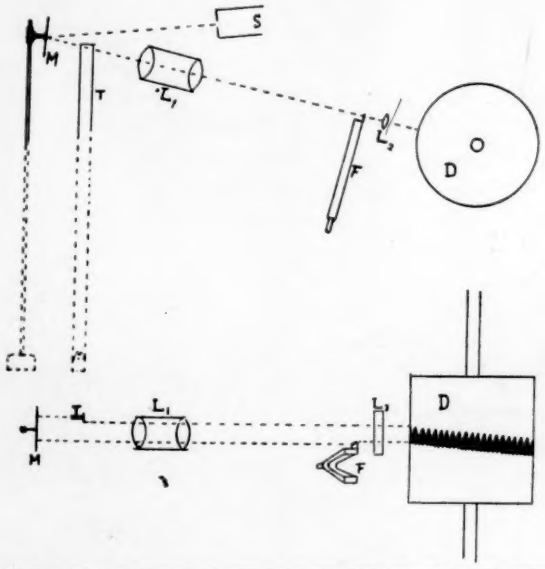
In my previous papers,[4] taking notice of the question regarding the inclination of a straight line in a logarithmic decrement and amplitude diagram, I have discussed the cause and mechanism of the phenomenon above mentioned somewhat in detail. Thus, the present investigation is said, also, to be that which supplies the necessary data for the previous work.

§2. EXPERIMENT.

(a) Apparatus.

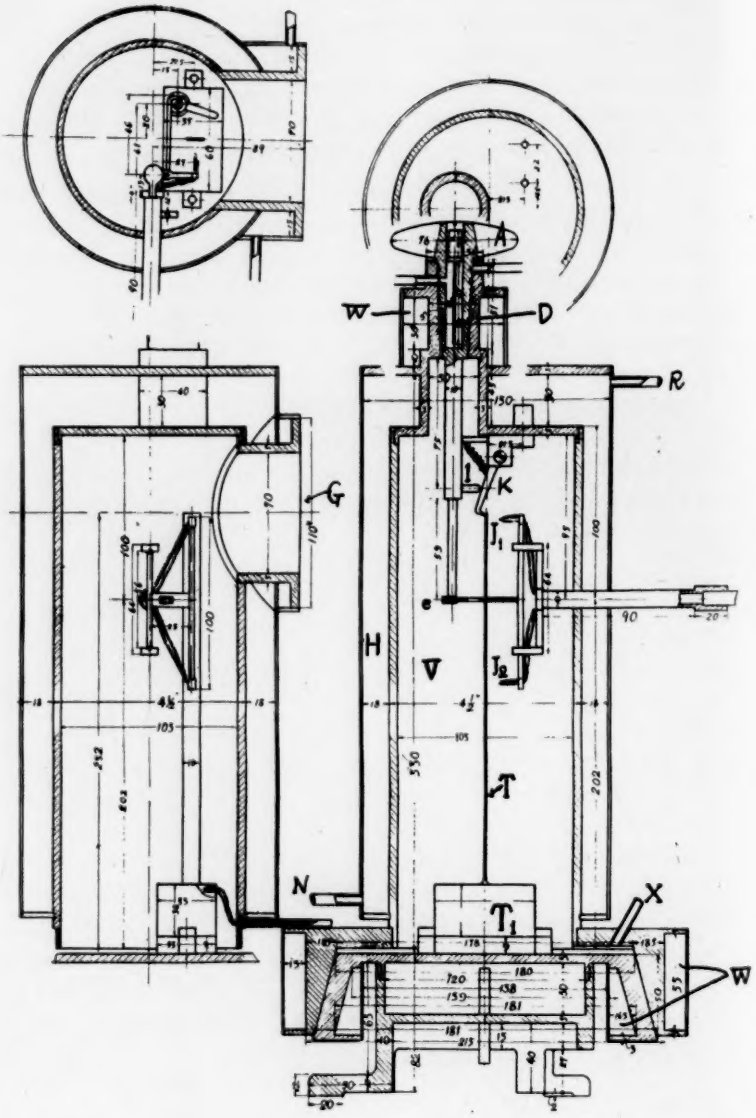
The main part of the apparatus used in the present experiment is shown in Fig. 1_1 and Fig. 1_2. In Fig. 1_1, general views

FIG. 1_1.



[4] Sci. Rep. Tôhoku Imp. Univ. Prof. Honda's Aniversary Volume (1936), 158, or Tech. Rep. Tôhoku Imp. Univ., XII (1937), 69.

FIG. 12.



of the experimental apparatus are shown where S, M, T, L_1, F, L_2 and D denote respectively the light source, fixed plane mirror, test-piece, lens, tuning fork, cylindrical lens and rotating drum covered with bromide paper. A part of the ray reflected at M (Fig. 1_1) after passing through the head of the test-piece, L_1, the lower part of the arm of the tuning fork, and L_2, strikes finally on the bromide paper covering D.

Figure 1_2 shows the vacuum vessel in which the test-piece vibrates, and the various notations contained in the diagram are explained as follows:

(A) Cock made of gun-metal which can rotate on its own position together with (I) and (e). (D) Support of (A) providing a water chamber for the purpose of protection against overheating of a part of contact of (A). (G) Glass window from which the ray passes in and out of the vessel. (H) The chamber of hot water or steam, and R and N the two mouths of this chamber. (V) Vacuum vessel made of brass. (X) The mouth of V which connects with the vacuum pump. (T) Test-piece. (T_1) The holder of (T) which is constructed in one with (T). (K) A nail having a strong spring which can rotate in the plane of diagram. (I) A projection of the rod connected to the vacuum cock (A) (the rotation of (I) enables (K) to move backwards and forwards). (e) A cam, fitted on the rod above mentioned, belongs to a part of the apparatus for temperature measurement. (J_1), (J_2) Thermocouples.

By rotating (A) and (I), (K) travels forwards and, at the same time, excites the motion of the test-piece in the plane of figure and at the instant when (I) separates from (K) it returns so quickly to its original position that it does not interfere with the motion of the test-piece. The first amplitude of the free end of the test-piece experimented with is adjustable by changing the length of (I). In this experiment, since the room-temperature was same throughout, explanation of the mechanisms for temperature measurement in the figures is omitted.

(b) Test-piece.

The size, dimensions and the heat treatment of the test-pieces are given in Fig. 2_1. The test-piece consisted of a part of thin beam, and the block of the specimen holder is placed in

two holes (having a diameter of 6 mm.) with bolts to the platform of the floor of the vacuum vessel.

Now, I have arrived at the point for giving the reasons for choosing, in our experiment, the kind of test-piece that is shown in the above diagram.

There should be no need to add here a discussion illustrating the unsuitability to us of the following methods of clamping the test-piece, viz.,

FIG. 21.

Materials	Annealing temperature
Brass	460°C
Cu	320° "
Al	400° "
Duralumin	300° "
Mild steel	850° "
Ag	400° "
Zn	210° "
Ni	850° "

(i) Clamping the test-piece with a horizontal vice; Since we have no means of knowing easily the contact-pressure of the two bodies, to define the exact degree of clamping seems difficult.

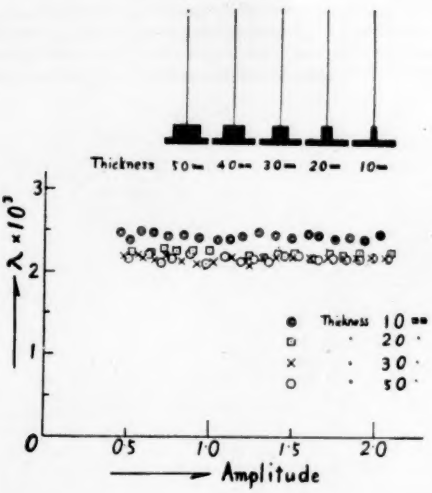
(ii) Using the tapering test-piece; Owing to the somewhat ill-defined shapes of its two ends, the measurement of the correct length of such a test-piece is undoubtedly difficult.

The most desirable conditions for clamping seem to me to be as follows: Without regard to the shape and dimensions of the test-piece, the energy transition must occur through the clamped end of the test-piece, depending only upon the properties of the material of which it is made. Accordingly the most desirable conditions for a cantilever are that (1) it

stands at the surface of the semi-infinite solid and (2) they are composed of one body.

Though I have tried to choose a test-piece of the shape fulfilling the above conditions as nearly as possible, yet the question of determining the dimensions of the parts of the holder still remained. For the purpose of determining these dimensions, 12 test-pieces made of brass having holders of different dimensions as shown in Fig. 2_2 were experimented

FIG. 2_2.

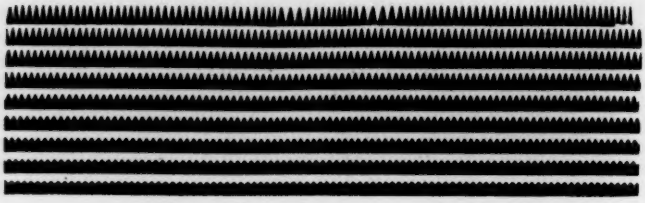


with under the conditions of a constant temperature and a pressure of 1/2000 mm. in Hg, and finally the logarithmic decrement, and amplitude diagrams corresponding to them were obtained. The data of the results of the experiments with 5 of these test-pieces are shown in Fig. 2_2, proving the fact that when the breadth of the holder is about 30 mm. or 40 mm., the dimensions of that part have no effect upon the damping nature of the oscillating test-pieces, as shown clearly in the figure. However, speaking strictly, the dimensions above pointed out, i.e. 30 mm. or 40 mm., are considered for test-pieces made of brass only, so that, in this experiment, I have chosen a dimension of 50 mm. on the assumption that this dimension common to all fulfil approximately the condition of minimum constant logarithmic decrement.

(c) **Results of Experiments.**

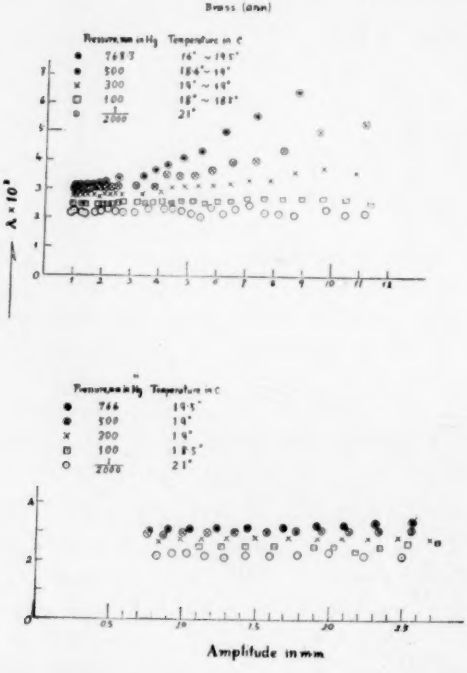
An oscillation of the test-piece and an oscillation of the tuning fork are photographed on the bromide paper covering the rotating drum D in Fig. 1_1. Fig. 3 is a part of the photo-

FIG. 3.



graph obtained by the experiment just described. In taking this photograph, an exposure of about one minute is usually needed, and from these photographs the amplitude can be

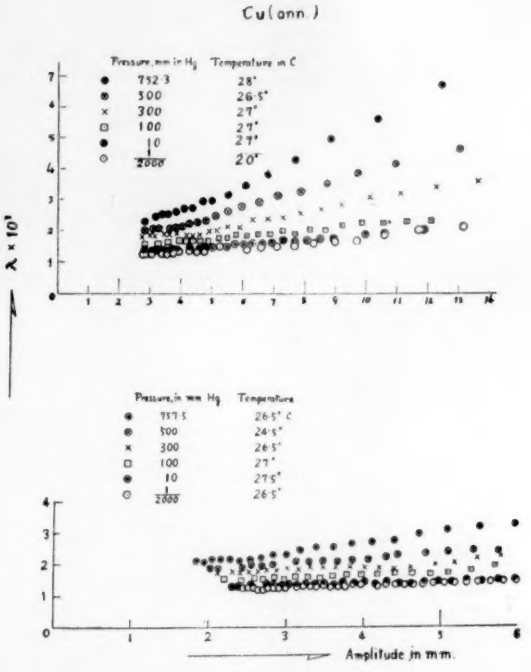
FIG. 4_1.



read accurately to 1/10 mm. Further, with regard to the pressure, we have used the state of 1/2000 mm. in Hg in place of vacuum, and except in some special cases, pressures lower than 1/2000 mm. in Hg are not here used.

Now by observing the photographs shown in Fig. 3, we can construct the logarithmic decrement, and amplitude diagrams as shown in Fig. 4. From the characteristics of the logarithmic

FIG. 42.



decrement above mentioned, the materials employed are very conveniently classified into the two following groups, that is,

{Brass group: Brass, Cu, Al, and Duralumin.
{Steel group: Mild steel, Zn, Ag.

From the logarithmic decrement, and amplitude diagrams for the brass group shown in Fig. 41—Fig. 44, the following conclusion may easily be drawn.

FIG. 43.

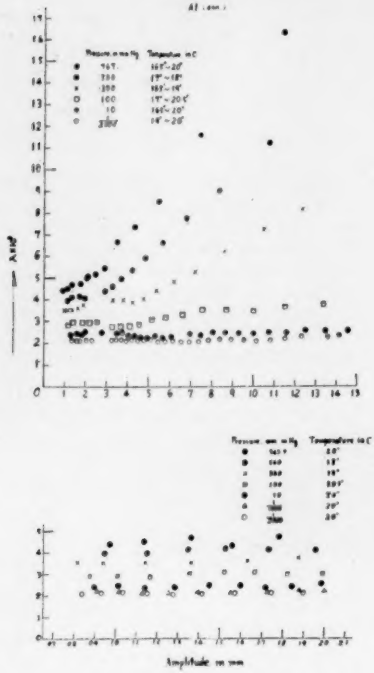
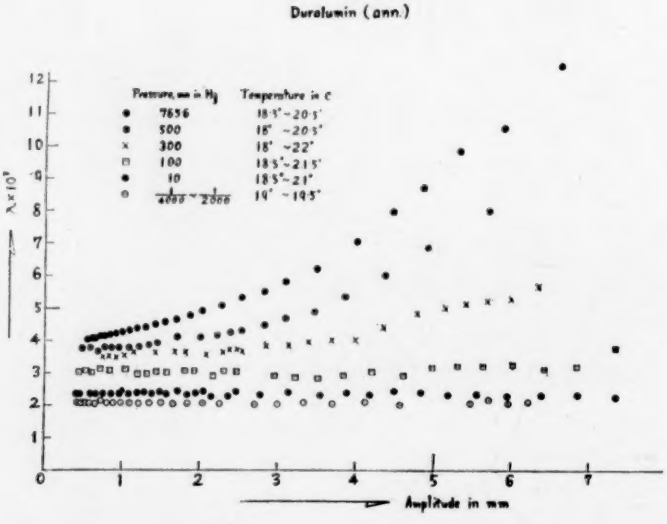


FIG. 44.


Duralumin (ann.)
Pressure, cm in Hg
Temperature in C
7656
18·5° ~ 20·5°
500
18° ~ 20·5°
300
18° ~ 22°
100
18·5° ~ 21·5°
10
18·5° ~ 21°
1/4000 ~ 1/2000
19° ~ 19·5°
λ × 10³
Amplitude in mm

(1) λ (logarithmic decrement) corresponding to small amplitude is constant, independent of the amplitude and, also, of the pressure of the surrounding medium.

(2) If the amplitude (y) becomes great, then the curves in λ, y diagrams have generally tilted to one side owing to the pressures experimented with. And it is remarkable that if the inclined curves (for the range of small amplitude, it is assumed as the inclined straight lines) above mentioned are exterpolated to a range of small amplitude, they will intersect approximately at a point on the axis of the logarithmic decrement. Indeed, we know that the proposition here mentioned is not new to us, because it has already been put forward by Prof. Sezawa in his paper cited above.

On the other hand, in the case of the steel group shown in Fig. 45—Fig. 47, the inclination of the curves of λ, y diagram above mentioned is somewhat remarkable compared with those of the brass group. Though, in the case of the steel group, the curves in the diagram have tilted to one side in the range of common amplitude, yet, in the range of small amplitude, it

FIG. 45.

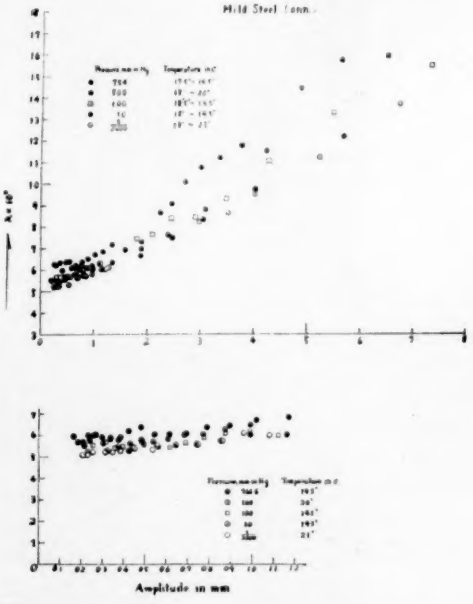


FIG. 46.

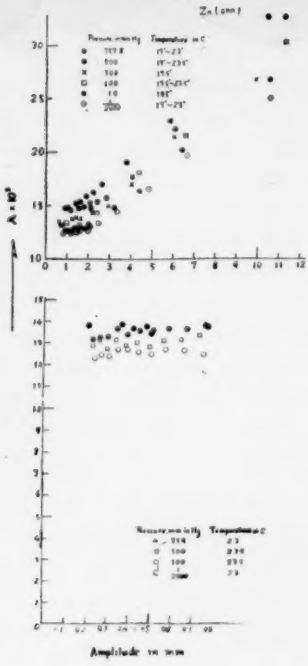
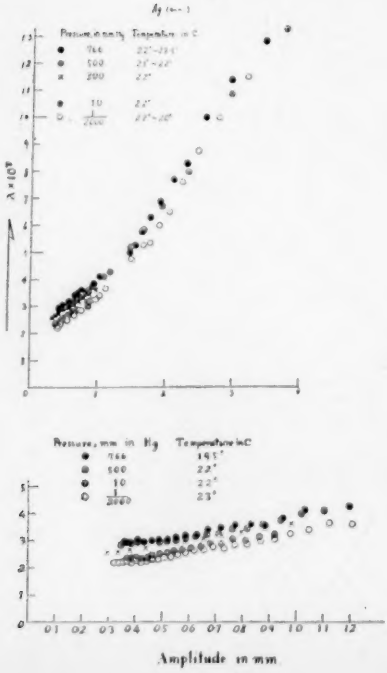


FIG. 47.



may easily be recognised that the groups of curves are constructed similarly to those of the horizontal straight lines such as those of the brass groups.

§3. CONSIDERATION OF THE EXPERIMENTAL RESULTS.

(1) Explanations regarding the parallel straight lines in a range of small amplitude in the λ, y diagram.

Although introducing the conception of the internal viscosity of a solid, a horizontal straight line under the pressure of 1/2000 mm. in Hg is easily explained, yet the question why the straight lines corresponding to the several pressures experimented with are, even in the range of small amplitude, parallel to the above mentioned straight line must be answered. A conclusion that the phenomena in question being explained by the surrounding pressure is arrived at in the following manner: Consider first the logarithmic decrements for several materials corresponding to any pressure which are shown in the upper part of Table 1, and subtract the logarithmic

TABLE 1.

$\rho(\lambda \sim \lambda_{1/2000}) = Constant.$

Materials	$\lambda_{\frac{1}{2000}}$	λ_{10}	λ_{100}	λ_{300}	λ_{500}	$\lambda_{745\sim765}$
Brass (ann.)	2.16×10^{-3}	2.27×10^{-3}	2.50×10^{-3}	2.76×10^{-3}	2.96×10^{-3}	3.10×10^{-3}
Cu (ann.)	1.25×10^{-3}	1.35×10^{-3}	1.50×10^{-3}	1.75×10^{-3}	1.85×10^{-3}	2.10×10^{-3}
Al (ann.)	2.10×10^{-3}	2.38×10^{-3}	2.90×10^{-3}	3.53×10^{-3}	3.95×10^{-3}	4.35×10^{-3}
Duralumin (ann.)	2.07×10^{-3}	2.35×10^{-3}	3.00×10^{-3}	3.50×10^{-3}	3.77×10^{-3}	4.02×10^{-3}
Mild steel (ann.)	5.13×10^{-3}	5.25×10^{-3}	5.45×10^{-3}		5.66×10^{-3}	5.90×10^{-3}
Ag (ann.)	1.90×10^{-3}	1.99×10^{-3}		2.25×10^{-3}	2.30×10^{-3}	2.49×10^{-3}
Zn (ann.)	12.45×10^{-3}		12.85×10^{-3}		13.16×10^{-3}	13.50×10^{-3}

Materials	ρ	$\rho(\lambda_{10}-\lambda_{\frac{1}{2000}})$	$\rho(\lambda_{100}-\lambda_{\frac{1}{2000}})$	$\rho(\lambda_{300}-\lambda_{\frac{1}{2000}})$	$\rho(\lambda_{500}-\lambda_{\frac{1}{2000}})$	$\rho(\lambda_{760}-\lambda_{\frac{1}{2000}})$
Brass (ann.)	8.496	0.935×10^{-3}	2.889×10^{-3}	5.098×10^{-3}	6.796×10^{-3}	7.986×10^{-3}
Cu (ann.)	8.950	0.895×10^{-3}	2.238×10^{-3}	4.475×10^{-3}	5.370×10^{-3}	7.607×10^{-3}
Al (ann.)	2.690	0.753×10^{-3}	2.152×10^{-3}	3.847×10^{-3}	4.977×10^{-3}	6.053×10^{-3}
Duralumin (ann.)	2.802	0.785×10^{-3}	2.606×10^{-3}	4.007×10^{-3}	4.763×10^{-3}	5.464×10^{-3}
Mild steel (ann.)	7.871	0.958×10^{-3}	2.519×10^{-3}		4.172×10^{-3}	6.060×10^{-3}
Ag (ann.)	10.648	0.945×10^{-3}		3.727×10^{-3}	4.685×10^{-3}	6.708×10^{-3}
Zn (ann.)	7.175		2.870×10^{-3}		5.094×10^{-3}	7.175×10^{-3}

decrement at the absolute zero pressure (1/2000 mm. in Hg) from the above mentioned values, and lastly multiplying them by the corresponding density of test materials, we shall obtain some constants depending only on the pressure and not on the material used.

The equation of motion of a beam in vacuum is [5]

$$y'' + 2\sigma b_0 y' + \sigma^2(1 + b_0^2)y = 0,$$

where y is the amplitude, σ, 2π times the frequency, σb_0, time constant.

The logarithmic decrement (πb_0) corresponding to the motion in question is no other than $\lambda_{1/2000}$ in Table 1, and $(\lambda_{10} - \lambda_{1/2000})$, $(\lambda_{100} - \lambda_{1/2000})$ etc. are the logarithmic decrements corresponding to the pressure 10 mm. in Hg, 100 mm. in Hg etc. measured from $\lambda_{1/2000}$. Here, from a close inspection of the equation of motion above mentioned, we see that the above quantities $(\lambda_{10} - \lambda_{1/2000})$, $(\lambda_{100} - \lambda_{1/2000})$ etc. contain the density in its denominator, so that multiplying $(\lambda_{10} - \lambda_{1/2000})$ etc. by the corresponding density, we obtain the result showing that the quantities thus obtained are the only function of pressure and not of their materials as shown in Table 1.

Regarding the above consideration, we can easily conclude that the parallel horizontal straight lines in the λ, y diagram are due entirely to the effect of surrounding pressure upon the damping of the flexural oscillation.

(2) The meaning of the inclination of the asymptotes in a λ, y diagram.[6]

In the range of low pressure, it is clear that "a" in the equation of the asymptote above mentioned, viz.,

$$\lambda = ay + b,$$

is a linear function of pressure as shown in Table 2 and Fig. 5. In this connection, we can express the same situation as

$$a = cp + d,$$

[5] Though, for the sake of simplicity, we will discuss the relation between λ and y with the usual equation of simple harmonic, yet, it may be said, that the result here obtained may immediately be applicable in interpreting the same phenomena occurring in the vibration of a beam.

[6] Notwithstanding the serious difference of the features of the λ, y diagram obtained from the Brass and Steel groups respectively, I am obliged here to study the various properties shown by them on the standpoint of the correspondence of an amplitude. On this point, a somewhat complete discussion will be published in the near future.

TABLE 2.

Table of a, c and d.

$\lambda = ay + b$
$a = cp + d$
$c = f$ (frequency)

Brass	pressure mm in Hg	768.3	500	300	100	
	a	0.645×10^{-3}	0.264×10^{-3}	0.133×10^{-3}	0.028×10^{-3}	
	$c = 0.53 \times 10^{-6}$		$d = 0$		$f = 11.2$	
Cu	pressure mm in Hg	752	500	300	100	10
	a	0.517×10^{-3}	0.280×10^{-3}	0.194×10^{-3}	0.0814×10^{-3}	0.0571×10^{-3}
	$c = 0.64 \times 10^{-6}$		$d = 0$		$f = 12.28$	
Al	pressure mm in Hg			300	100	
	a			0.38×10^{-3}	0.11×10^{-3}	
	$c = 1.16 \times 10^{-6}$		$d = 0$		$f = 17.11$	
Duralumin	pressure mm in Hg			300	100	
	a			0.36×10^{-3}	0.117×10^{-3}	
	$c = 1.06 \times 10^{-6}$		$d = 0$		$f = 16.82$	
Mild steel	pressure mm in Hg	754	500		100	
	a	2.303×10^{-3}	1.88×10^{-3}		1.688×10^{-3}	
	$c = 1.0 \times 10^{-6}$		$d = 1.5 \times 10^{-3}$		$f = 17.01$	
Ag	pressure mm in Hg	766	500	300		10
	a	2.095×10^{-3}	2.05×10^{-3}	1.995×10^{-3}		1.951×10^{-3}
	$c = 0.2 \times 10^{-6}$		$d = 1.94 \times 10^{-2}$		$f = 9.08$	
Zn	pressure mm in Hg	757.8	500	300	100	
	a	2.014×10^{-3}	1.97×10^{-3}	1.82×10^{-3}	1.70×10^{-3}	
	$c = 0.48 \times 10^{-6}$		$d = 1.68 \times 10^{-3}$		$f = 11.24$	

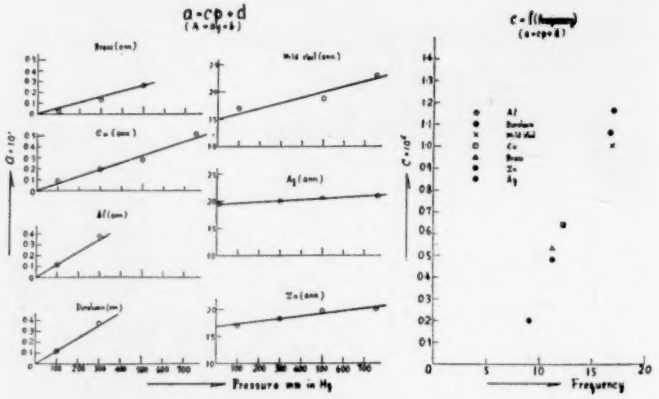
where p, and (c, d) denote the pressure and constants respectively.

If we denote the pressure using the height of mercury in mm., we have

$$\begin{cases} d = 0 & \text{for Brass group,} \\ d = 1.5 \sim 2.0 & \text{for Steel group.} \end{cases}$$

At this point, we will add some comments on the meaning of c. As is usually expected, the quantity c in our case must be a function of the frequency of the oscillating test-piece, and therefore c and the frequency diagrams as shown on the right hand side of Fig. 5 are constructed on this assumption.

FIG. 5.



Assuming the relation between c and the frequency as parabolic, I have constructed Fig. 6. From Fig. 6, if we denote the frequency as f, the following relations may be recognized as being probably true:

$$f^2 = kc.$$

(3) Determination of the coefficient of solid viscosity.

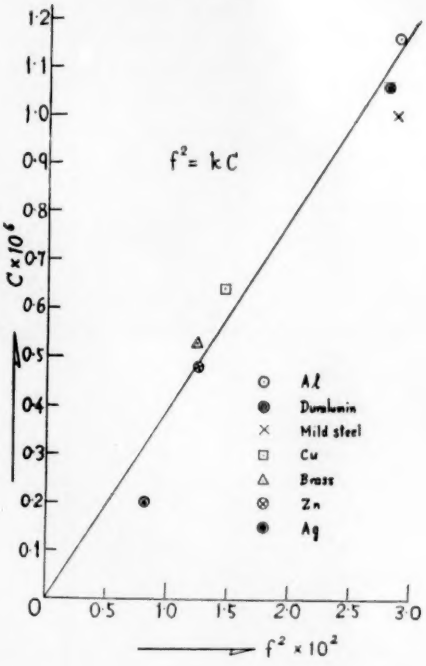
From a horizontal straight line in the λ, y diagram corresponding to the condition of zero-pressure, we can readily calculate the coefficient of solid viscosity as shown in Table 3.[7]

[7] The corresponding equation of motion is

$$\frac{\partial^2 y}{\partial t^2} + \frac{Ek^2}{\rho}\frac{\partial^4 y}{\partial x^4} + \frac{\mu k^2}{\rho}\frac{\partial^5 y}{\partial t \partial x^4} = 0.$$

In this table E, μ, l, ξ and k denote respectively Young's modulus, coefficient of viscosity, length of the test-piece, the first root of the frequency equation $\cos \xi l \operatorname{Cos} \xi l + 1 = 0$ and the radius of gyration of the cross-section about the axis through the centroid of the section perpendicular to the plane of vibration.

FIG. 6.



It is obvious from the table that the values of μ here obtained are 10^6 order in c.g.s., and among the various values hitherto published by previous investigators, the coefficients proposed by Professor Sezawa [8] closely coincide with ours, not only in their order but also in their several absolute values.

(4) A maximum stress at which the law of internal viscosity of solids may be applied.

An amplitude corresponding to the end of the horizontal line of a λ, y diagram obtained in the state of small amplitude

[8] *Rep. Aeron. Res. Inst.*, VII (1932), 195.

TABLE 3.

$$E = (2\pi f)^2 \frac{\rho l^4}{(\xi l)^4 k^2} = 3.1935 \frac{\rho l^4 f^2}{k^2}.$$

Materials	ρ	τ sec. $f = 1/\tau$	l cm	b cm	$E_{c.g.s.}$	Temperature
Brass (ann.)	8.4964	0.0893 11.1982	22.0085	0.0997	0.9795×10^{12}	19° C
Cu (ann.)	8.9500	0.0814 12.2850	22.1360	0.1018	1.1095×10^{12}	18.5° C
Al (ann.)	2.6900	0.0585 17.1086	22.1228	0.1019	0.6961×10^{12}	19° C
Duralumin (ann.)	2.8025	0.0595 16.8209	22.1522	0.0988	0.7502×10^{12}	21° C
Mild steel (ann.)	7.8707	0.0588 17.0097	22.0985	0.1011	2.0367×10^{12}	18° C
Ag (ann.)	10.6480	0.1101 9.0802	22.1385	0.1015	0.7851×10^{12}	23° C
Zn (ann.)	7.1751	0.0890 11.2373	22.1680	0.1004	0.8318×10^{12}	23° C

$$\mu = 2\lambda \frac{\rho l^4}{(\xi l)^4 k^2 \tau} = 0.16178 \frac{\rho l^4 f}{k^2} \lambda.$$

Materials	λ	$\mu_{c.g.s.}$	Temperature
Brass (ann.)	2.16×10^{-2}	0.9570×10^{7}	21° C
Cu (ann.)	1.25×10^{-2}	0.6182×10^{7}	20° C
Al (ann.)	2.10×10^{-2}	0.4327×10^{7}	19.5° C
Duralumin (ann.)	2.07×10^{-2}	0.4676×10^{7}	19.5° C
Mild steel (ann.)	5.13×10^{-2}	3.1112×10^{7}	21° C
Ag (ann.)	1.90×10^{-2}	0.8321×10^{7}	23° C
Zn (ann.)	12.45×10^{-2}	4.6689×10^{7}	23° C

undoubtedly varies according to the material and the pressure, so that, in Table 4, I have calculated the maximum fiber-stress at the clamped end of the cantilever corresponding to the maximum amplitude just mentioned under the same pressure of 1/2000 mm. in Hg. As Fig. 4 shows plainly, the Brass groups have no inclination in the amplitude range given in the figure, so that the values of their stresses in Table 4 have no longer the meaning of the true maximum stress stated above.

From the above table, we learn some important characteristics in connection with this problem, which are that, in the steel group, the law of internal viscosity begins to deviate,

TABLE 4.

Max. Fiber Stress at the Critical Point.

Materials	Amplitude mm	Young's modulus $E \cdot 10^{-12}$	Stress $q \cdot 10^{-8}$	$(q/E) \cdot 10^4$
Brass (ann.)	12	0.9795	4.2192	4.3074
Cu (ann.)	6	1.1995	2.6286	2.1914
Al (ann.)	14	0.6961	3.5672	5.1250
Duralumin (ann.)		0.7502		
Mild Steel (ann.)	0.5	2.0367	3.7060	0.1820
Ag (ann.)	0.32	0.7851	0.0914	0.1165
Zn (ann.)	0.8	0.8319	0.2390	0.2873

$$q = E(0.5)\xi^2 A \frac{\sin \xi l \operatorname{Sin} \xi l}{\cos \xi l + \operatorname{Cos} \xi l}$$

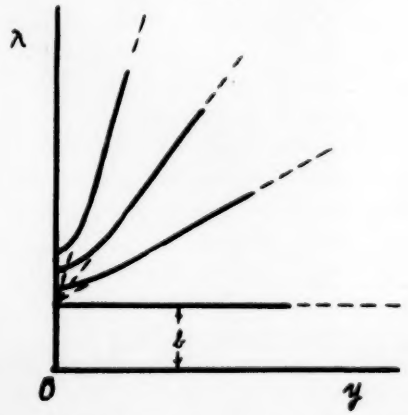
A = Amplitude, $\xi l = 1.8751$

against in the brass group, in the state of small stress at the clamped end of the test-pieces.

§4. CALCULATIONS CONCERNING THE RELATION BETWEEN THE LOGARITHMIC DECREMENT AND ITS CORRESPONDING AMPLITUDE.

The general features of the logarithmic decrement, and amplitude diagram (λ, y diagram), obtained in our experiment may be assumed as shown in Fig. 7$_1$. Though, in my previous

FIG. 7$_1$.



paper, an inclined straight line in the λ, y diagram is treated as one that gives directly the relation between λ and y, yet, by introducing the newly-obtained experimental results, it shows us plainly that the straight line above pointed out corresponds to merely an asymptote of the hyperbola passing through a point $(\lambda, 0)$.

In my previous paper, taking notice of the straight line above mentioned, that is,

$$\lambda = ay + b,$$

I discussed the cause and mechanism of the phenomena just mentioned in the following two manners:

1. In my first paper, I discussed the phenomenon in question which belongs to that within the limit of elasticity. Using the equation above cited, I deduced first the equation of motion corresponding to a type of oscillation in which the logarithmic decrement is proportional to successive extreme amplitude [9] and secondly, with regard to the expression of the decrease of damping ratio etc., I concluded finally that the phenomenon in question originated from the surrounding air pressure.

2. In my second paper, under the assumption that the phenomenon in question belongs to the elastic after-working in a wide sense, the same subject above mentioned was studied. Introducing the "coefficient d'hérédité" of Volterra's sense and constructing the integral equation in which the equation of the logarithmic decrement above mentioned is used,[10] we obtained the exact expression of "coefficient d'hérédité." Thus, the effect of the after-working upon the displacement, and, at the same time, the "coefficient d'hérédité" were discussed in detail.

Now, returning to the issue, let us consider Fig. 7$_2$ where an asymptote and its corresponding hyperbola are given.

It is clear that the hyperbola in the figure may be expressed as

$$(\lambda - b)^2 - a^2y^2 = \beta^2.$$

Or, we have

$$\lambda = \sqrt{(ay)^2 + \beta^2} + b. \tag{1}$$

---

[9] $y'' + 2\sigma b_0 y' + \sigma^2(1 + b_0^2)y = \frac{a}{\pi}(\sigma b_0 y + 2y')\left\{ - ay(\sigma b_0 y + y') \pm \left[(\sigma b_0 y + y')^2 + \sigma^2 y^2 \left(1 - \frac{a^2}{\pi^2} y^2 \right) \right]^{\frac{1}{2}} \right\} \left(1 - \frac{a^2}{\pi^2} y^2 \right)^{-1}$,

where $b_0 = b/\pi$. (Prof. Honda's Aniversary Volume (1936), 161, eq. (9).)

[10] $y = - \frac{1}{b^2 + \sigma^2} [y'' + 2by'] - \int_{t_0}^{t} [y'' + 2by']_{t'} \Phi(t - t')dt'$,

when Φ denotes the "coefficient d'hérédité" above mentioned. (Tech. Rep. Tôhoku Imp. Univ. XII (1937), 76, eq. (13).)

Here we will introduce the following expression of the logarithmic decrement obtained in my previous paper, that is,

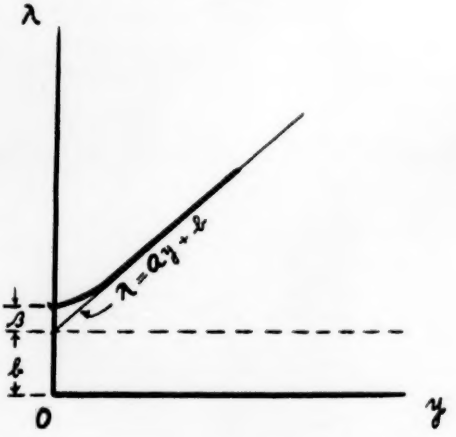
$$\lambda = -\frac{\pi}{\sigma}\frac{1}{y}\frac{dy}{dt}. \tag{1_1}$$

Combining (1) with (1_1), it becomes

$$\frac{dy}{y\{\sqrt{a^2y^2 + \beta^2} + b\}} = -\sigma_0 dt, \tag{2}$$

where $\sigma_0 = \sigma/\pi$.

FIG. 7₂.



Putting $y = 1/z$, $dy = -dz/z$ into (2), we will obtain the expression corresponding to the left-hand term of (2) as

$$-\frac{dz}{(\sqrt{a^2 + \beta^2 z^2} + bz)}. \tag{2_1}$$

Putting again

$$\beta z = \alpha \operatorname{Sin} x, \qquad dz = \frac{\alpha}{\beta}\operatorname{Cos} x dx,$$

into (2_1), where $\operatorname{Cos} x = \cos ix$ and $\operatorname{Sin} x = -i \sin ix$, it becomes

$$-\frac{\operatorname{Cos} x dx}{\beta \operatorname{Cos} x + b \operatorname{Sin} x} = -\sigma_0 dt. \tag{2_2}$$

For the purpose of obtaining the integral of (2_2), let us introduce a new function u as

$$\begin{cases} \beta \operatorname{Cos} x + b \operatorname{Sin} x = u, \\ \beta \operatorname{Sin} x + b \operatorname{Cos} x = \dfrac{du}{dx}, \end{cases}$$

or

$$\operatorname{Cos} x = \frac{\beta u - b\dfrac{du}{dx}}{\beta^2 - b^2}, \qquad \operatorname{Sin} x = \frac{bu - \beta\dfrac{du}{dx}}{b^2 - \beta^2}.$$

Writing (2_2) anew, after some simple calculations, it becomes finally as

$$-\sigma_0 t + C_1 = \frac{\beta}{b^2 - \beta^2} x - \frac{b}{b^2 - \beta^2} \log (\beta \operatorname{Cos} x + b \operatorname{Sin} x) \quad (3)$$

or

$$\frac{1}{b^2 - \beta^2}\left[\beta \log \frac{\beta + \sqrt{a^2y^2 + \beta^2}}{ay} - b \log \frac{b + \sqrt{a^2y^2 + \beta^2}}{ay} \right] = -\sigma_0 t + C, \quad (3_1)$$

where

$$C = C_1 + (b \log \beta)/(b^2 - \beta^2).$$

More briefly, (3_1) becomes

$$\left(\frac{\beta + \sqrt{a^2y^2 + \beta^2}}{ay} \right)^{\beta} \left(\frac{ay}{b + \sqrt{a^2y^2 + \beta^2}} \right)^{b} = Ae^{-\sigma_0(b^2 - \beta^2)t}. \quad (4)$$

This gives us the relation between a, b, β and y and owing to its complex features, it shows that the equation of motion corresponding to the present case could not easily be deduced from it. Accordingly, in this paper, I am obliged to deduce the equations corresponding to some simple special cases of (4).

Case 1. When β in (4) is very small.

This case corresponds to that in which the curve in the λ, y diagram may be assumed as a straight line.

The case where the following equation exists will first be considered,

$$\left(\frac{ay}{b+\sqrt{a^2y^2+\beta^2}}\right)^b = Ae^{-\sigma_0(b^2-\beta^2)t}, \tag{5}$$

or, arranging it in order we have

$$ay = (b+\sqrt{a^2y^2+\beta^2})A_1e^{-(\sigma_0/b)(b^2-\beta^2)t} \tag{5_1}$$

or

$$ay = \frac{1}{2\left\{1-\frac{1}{A_1^2}e^{2(\sigma_0/b)(b^2-\beta^2)t}\right\}}\left\{-\frac{2be^{(\sigma_0/b)(b^2-\beta^2)t}}{A_1} \pm \sqrt{\frac{4b^2e^{2(\sigma_0/b)(b^2-\beta^2)t}}{A_1^2}-4(\beta^2-b^2)\left[1-\frac{1}{A_1^2}e^{2(\sigma_0/b)(b^2-\beta^2)t}\right]}\right\}, \tag{5_2}$$

where $A_1 = A^{1/b}$.

Some special cases may be deduced as follows:

(*a*) Neglecting β^2 in (5_1) we have

$$ay = (b+ay)A_1e^{-\sigma_0bt}$$

or

$$y = \frac{bA_1e^{-\sigma_0bt}}{a(1-A_1e^{-\sigma_0bt})}. \tag{5_3}$$

This is an equation belonging to the same type of expression as was obtained in my previous second paper.

(*b*) Simplifying the terms in the bracket contained in (5_2), we arrive at the following expression

$$= 2b\sqrt{1-\frac{\beta^2}{b^2}\left(1-\frac{1}{A_1^2}e^{2(\sigma_0/b)(b^2-\beta^2)t}\right)} = 2b.$$

Introducing the above result into (5_2), it becomes finally

$$ay = \pm b\frac{1}{1\pm\frac{1}{A_1}e^{\sigma_0bt}}. \tag{5_4}$$

It shows plainly that the expression thus deduced coincides in its nature with (3) in my first paper.

Case 2. When b is very small.

This case corresponds to that in which the asymptotes in the λ, y diagram are assumed as intersecting at the origin of the co-ordinate.

We will consider the case in which equation (4) being assumed as

$$\left(\frac{\beta + \sqrt{a^2y^2 + \beta^2}}{ay}\right)^{\beta} = Ae^{-\sigma_0(b^2-\beta^2)t}. \tag{6}$$

Arranging it in order, we have

$$ay = \frac{\sqrt{a^2y^2 + \beta^2} + \beta}{A_0e^{-(\sigma_0/\beta)(b^2-\beta^2)t}} \tag{6_1}$$

or

$$ay = \frac{1}{2\{1 - A_0^2e^{2\sigma_0\beta t}\}}\{-2\beta A_0e^{\sigma_0\beta t} \pm \sqrt{4\beta^2A_0^2e^{2\sigma_0bt} + 4\beta^2[1 - A_0^2e^{2\sigma_0bt}]}\}, \tag{6_2}$$

where $A_0 = A^{1/\beta}$.

Treating (6_2) similarly to the case 1, we have arrived at the result

$$ay = \beta\frac{1}{1 \pm A_0e^{\sigma_0\beta t}}. \tag{6_3}$$

It may be worth pointing out here that the quantities b and β are connected by (5) and (6) to the displacement, time etc. in the phenomena of damping.

Case 3. When y in (4) is very small.

Here, the case in which the following assumptions are recognized is considered, viz.,

$$\sqrt{a^2y^2 + \beta^2} = \beta, \text{ etc.}$$

Equation (4) becomes for the case, as

$$\left(\frac{2b}{ay}\right)^{\beta}\left(\frac{ay}{b+\beta}\right)^{b} = Ae^{-\sigma_0(b^2-\beta^2)t} \tag{7}$$

or

$$\frac{(2b)^{\beta}}{(b+\beta)^{b}}(ay)^{b-\beta} = Ae^{-\sigma_0(b^2-\beta^2)t}.$$

More briefly, we have

$$y = \frac{1}{a}\left\{ A \frac{(b-\beta)^b}{(2b)^\beta} \right\}^{1/(b-\beta)} e^{-\sigma_0(b+\beta)t}. \qquad (7_1)$$

On the other hand, using (1_1), we shall arrive directly at the same result expressed by (7_1) starting with the relation

$$-\frac{1}{\sigma_0}\frac{1}{y}\frac{dy}{dt} = b + \beta.$$

CONCLUSION.

In this paper, using new types of cantilever test-pieces made of 7 different metals and, moreover, taking the various necessary precautions for this kind of experiment, I have obtained the data of the damping characteristics for several metals. Based on these experimental results, the laws of internal resistance of solids are inquired into, and in conclusion thereof it is recognized that the law of viscous resistance is valid, especially in the state of small stresses.

In the last part of this paper, as a continuation of my mathematical considerations regarding the cause and mechanism of the phenomena in question, some simple calculations, concerning the relation between the logarithmic decrement and its corresponding amplitude obtained, are added.

In conclusion, my sincere thanks are due to the President of our University Dr. K. Honda under whose suggestion and direction this investigation has been carried out.

New Generator Design Isolates Double Frequency Vibration.—(*Power Plant Engineering*, Volume 44, No. 12.) Double frequency vibration, heretofore a special problem in two-pole turbine-generators, has been practically eliminated by General Electric in a spring mounted, 3600 r.p.m. generator recently installed in the Westport station of the Consolidated Gas, Electric Light and Power Co., of Baltimore. The new generator, recently installed, is the first of its type to be put into operation. The spring mounted design of the 2500 kw. turbine generator isolates vibration so well that it is impossible for a man standing alongside the generator to tell, either by sound or by touch, when excitation is applied or removed. Such an amazing reduction is accomplished by the use of a flexible mounting for the stator structure. Isolating the vibration at its source and confining it to the laminated core, this resilient core mounting does away with the annoying 120 cycle "transformer hum" which has always been characteristic of large high speed generators under excitation. Also transmission of the double frequency 7200 per minute disturbances to the foundation and nearby structure is prevented. While simple in construction, the resilient core mounting involves a great many considerations in design. Heretofore the laminated core has been stacked on long dovetail "key bars," or "ribs," which have been attached directly to the frame. In the new construction, the same "key bars" are employed but are attached to twin sets of spring-bars which in turn are joined to the frame in such a way as to provide flexibility between the "key bars" and the frame. Vibrations are thus absorbed by a flexible mounted core, resilient enough to prevent them from being transmitted to the frame.

R. H. O.

GEIGER-MUELLER COUNTERS.

BY

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Bartol Research Foundation of The Franklin Institute, Swarthmore, Pa.

Although Geiger counters have been used in the laboratory since their first application by Rutherford and Geiger in 1908,[1] it is only within the last decade that studies of the cosmic radiation have demanded the production of quantities of counters which are reliable and stable in use. This demand has been met by several laboratories, and several empirical procedures for making good counters have been used. These successful procedures were developed by a cut and try method without a very clear understanding of the actual mechanism of Geiger counter action. As the field of cosmic radiation developed, more exacting demands were made upon the counters, and it became necessary to investigate in greater detail the counting mechanism with a view to improving counter characteristics further, and to learning the most advantageous conditions under which to operate counters. Within the last year we have developed a picture of the counter mechanism [2] which seems entirely satisfactory. With this deeper understanding of the process involved, it becomes desirable to review the methods of construction and application of counters, and to show what the empirical procedures accomplish and how they are justified.

FUNDAMENTAL CONSIDERATIONS AND DEFINITIONS.

If two electrodes are immersed in a gas and a potential difference is created between them, no current will flow until an ion is formed in the gas, and drifts to an electrode. If the potential difference is sufficiently high, the original ion will create others by the so-called process of "ionization by collision" as it travels toward the electrode, and we will have an

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[1] E. Rutherford and H. Geiger, *Proc. Roy. Soc.*, **A81**, 141 (1908).

[2] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **57**, 1030 (1940).

amplification of the original amount of charge. If the potential is increased, the amount of amplification increases and, if the conditions are suitable, a steady, self-maintained current may occur between the electrodes. However, it should always be possible, theoretically, to connect the electrodes to an electrical circuit employing vacuum tubes or similar devices, such that when the charge collected reaches a certain value, the potential difference between the electrodes is reduced to the extent that the process is terminated. The whole apparatus will then recover and await the appearance of the next ion between the electrodes. The action of the apparatus may be recorded in any desired manner and the device as a whole represents an ion counter. Such a device may, of course, take almost any form, the only limitations being those of the experimentalist in devising the appropriate electrical circuits.

If the form and material of the electrodes are properly chosen, and if the initial potential difference and the pressure of the gas are correctly adjusted, then the "quenching" circuit may be greatly simplified or may become entirely unnecessary. For example, in the original work of Rutherford and Geiger,[1] a positively charged wire, placed coaxially with a cylinder, was used without a quenching circuit, to count alpha particles. Geiger and his collaborators [3] later used a positive or negative point or ball inside a metal shell to count either alpha particles alone or, with a somewhat higher potential on the point, both alpha and beta particles. The form of counter most commonly used today is that consisting of a fine, positively charged wire coaxial with a metal cylinder. Although this is identical with Rutherford's and Geiger's original counter, its particular advantage of having a large available sensitive area was first emphasized by Geiger and Mueller,[4] and such counters are now generally known as Geiger-Mueller counters.

To obtain the desired counting action of the counter tube, it is necessary to adjust the potential between the electrodes to the proper value. Let us, for the sake of clarity, take the potential of the outer cylinder as zero, and examine what

[3] H. Geiger, *Phys. Zs.*, **14**, 1129 (1913); H. Geiger and E. Rutherford, *Phil. Mag.* (6), **24**, 618 (1912); H. Geiger and O. Klemperer, *Zs. f. Physik*, **49**, 753 (1928).

[4] H. Geiger and W. Mueller, *Phys. Zeits.*, **29**, 839 (1928); **30**, 489 (1929).

happens when groups of ions are formed between the electrodes, maintaining the wire at various positive potentials. Let us suppose that the wire is not connected to anything, so that no complications from any sort of quenching action can arise. Figure 1 shows the quantity of charge collected by the

FIG. 1.

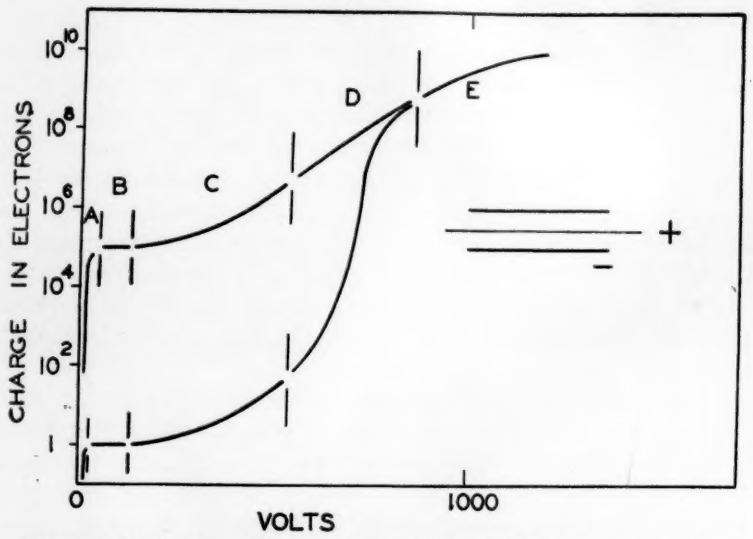


Illustration of the various regions of potential showing the multiplication of an original amount of ionization by the discharge processes in a tube with coaxial cylindrical electrodes. The final charge collected is plotted vertically on a logarithmic scale and the initial potential difference is plotted horizontally on a linear scale. The upper curve represents the case where initially 10^5 ion pairs are created, the lower curve that for a single ion pair. Region E is called the Geiger-Mueller region.

wire, on a logarithmic scale, as a function of the wire potential. The two curves correspond to two numbers of ion pairs originally produced. The lower curve corresponds to the formation of a single ion pair, while the upper curve represents an initial ionization of 10^5 ion pairs, such as an alpha particle might produce. At very low potentials, in region *A*, Fig. 1, not even all of the ions formed will be collected, since some recombination will take place. At higher potentials, saturation is attained, in region *B*. In region *C*, the potential is sufficiently high so that some ionization by collision takes place, and the amount of amplification increases with the potential. The amplification in this region is independent of

the initial ionization, and the two curves in Fig. 1 are parallel. It is in this region that proportional counters are operated. At high potentials, region *D*, the two curves approach each other, and we have a region of non-proportional amplification. The two curves meet at the beginning of region *E*, which we call the Geiger-Mueller region, since Geiger-Mueller counters operate at these potentials. This range of potential is characterized by the fact that the total amount of ionization produced is independent of the initial amount of ionization. Region *E* will be the region of our chief interest below.

If the surfaces of the electrodes have the proper characteristics, which will be discussed later, the pulses of charge which the wire receives will lower its potential, and this lowering may be recorded. The device then acts as a counter. Some means must, of course, be provided to allow the potential of the wire to recover to its initial value after a count occurs. This is most simply accomplished by the use of a high resistance through which the charge collected by the wire may leak off again.

If our counter is exposed to a weak source of radiation, then it is possible to indicate the kinds of behavior shown in Fig. 1 in another manner. Suppose we plot, as in Fig. 2, the number of counts occurring in a given interval of time, as ordinates, against the potential upon the counter, as abscissæ. This curve may be called the *counter characteristic curve* in analogy with vacuum tube characteristics, and usually has the shape shown by the solid line in the figure. The counter acts as a Geiger-Mueller counter at potentials above the value V_s which marks the beginning of the plateau, and these potentials correspond to region *E* of Fig. 1. The pulses which the counter produces are thus all of the same size.

As we go to potentials below V_s, the counting rate decreases in a manner which is more characteristic of the particular amplifier and recorder used to determine the counting rate, than of the counter itself. The size of the pulses also decreases with potential in this region and the pulses vary in size from one to another, the distribution spreading out more and more as we go to lower and lower potentials. Our amplifier and recorder will not respond to the smallest pulses, and we will measure a decreased counting rate. We have indicated

two curves for different amplifier sensitivities, the line beginning at the point p being that observed with a more sensitive amplifier than that used to measure the other line.

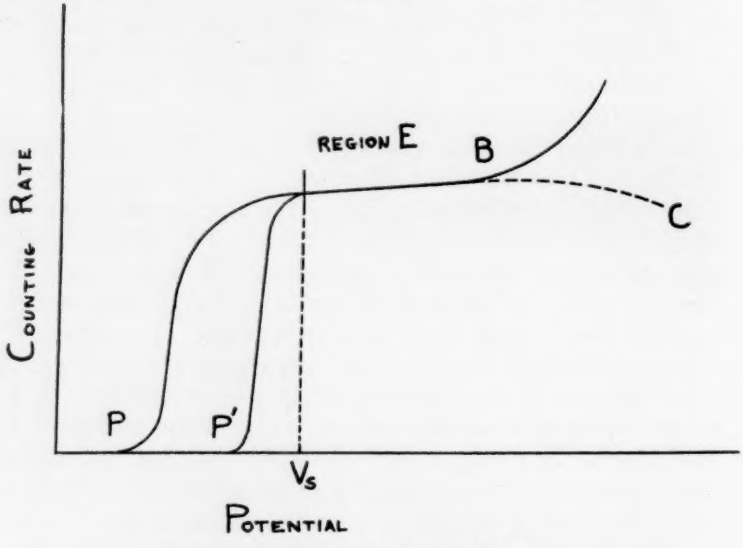
The point p, or p', as the case may be, that is, the potential at which counts begin to be recorded, is customarily defined as the starting potential of the counter. We prefer, however, to define as the starting potential of the counter, the potential corresponding to the point V_s, that is, the *minimum potential at which all pulses have the same size and at which the plateau of the counter characteristic begins.* In this way, the starting potential is defined so as to be independent of the sensitivity of the amplifier and recorder used, and thus represents a better parameter with which to describe a particular counter than any potential such as p. To be sure, if we had a very insensitive amplifier, the counter characteristic measured would fall to zero before the potential was lowered as far as V_s, and we must assure ourselves that this is not the case if we wish to measure the true starting potential. The distinction between the definition of starting potential used here and the more usual one is more a question of logic than otherwise, since in practice the difference between p and V_s does not amount to more than about two or three per cent. of V_s.

At the potential corresponding to the point B in Fig. 2, the counting rate begins to rise again, although the source of radiation remains at a constant intensity. The counter is thus producing discharges which do not depend upon the external radiation. Such discharges are known as spurious counts. The phenomenon is designated as the self-excitation (Selbsterregnung) of the counter. It is the most important single factor in determining the worth of a counter, and we shall have much more to say about it in succeeding sections. If a counter is used with a low leakage resistance, the characteristic may not rise as shown in Fig. 2, but the counting rate may decrease at the higher potentials, as indicated by the dotted curve C in the figure. In this event, we find that the counter is breaking into discharges which last much longer than the usual ones, and is approaching the condition of a self-maintained discharge. The occurrence of spurious counts does not enter the picture. A counter characteristic of the form shown by the curve C can always be altered to the other form

which rises with potential by employing a sufficiently high leakage resistance.

A counter should be operated at some potential between V_s and that which corresponds to B in Fig. 2. A satisfactory counter will have a negligible number of spurious counts under operating conditions, and will deliver pulses all of nearly the same size. The difference between the operating potential and the starting potential, V_s, is known as the *over-voltage* at which the counter is operated. The size of the pulses which

FIG. 2.



The characteristic curve of a Geiger-Mueller counter.

the counter delivers depends upon this over-voltage as one parameter.

Whether or not the plateau of the counter characteristic is limited by spurious counts or by the approach to a self-maintained discharge, or whether, indeed, there is any plateau at all, is largely determined by the condition of the cathode surface of the counter (the cylinder). The routines which have been devised for the preparation of good counters all have the fundamental purpose of conditioning this surface properly. In what follows we shall first present the methods of con-

struction which have been used at the Bartol Research Foundation, and then attempt to analyze them in order to see just what they have accomplished toward the production of good counters. Although other methods will undoubtedly produce counters which are fully as satisfactory, we shall confine ourselves to this one only. In any event, the ends to be attained will be identical. Once it has been clearly established just what is necessary to be done, improvements in the methods of preparation must almost necessarily follow from further experimental investigation of the problems.

THE CONSTRUCTION OF COUNTERS.

The exact mechanical design of a counter naturally depends to a large extent upon the purpose for which the counter is to be utilized. We shall, therefore, describe below some specific examples of counters which have been made and successfully used at the Bartol Research Foundation. We shall endeavor to emphasize, however, those points of design which should be incorporated, if possible, in *all* counters. In this way one should be able to apply these principles in the construction of a counter of any size or shape required for a particular problem.

The first point to be considered might be called the chemical stability of the counter. It is well known that in the processes which make up what is known as a gaseous discharge, the collisions among the molecules of the gas and the collisions between the gas molecules and the surfaces of the electrodes are much more violent and energetic than those which occur in a test tube where an ordinary chemical reaction is taking place. Indeed, the difference is so striking that the reactions which take place in a discharge tube are not generally considered as belonging to the realm of chemistry at all. Even in the less intense form of discharge which occurs in a Geiger-Mueller counter, these violent reactions take place. Consequently, a primary consideration in the construction of counters should be that their composition, both gaseous and in regard to the electrodes and their surface layers, should not alter with time. We must, therefore, insure that the counter is a closed system. The best manner of accomplishing this that we know today is to enclose the counter in a glass envelope, using the best of modern high-vacuum technique in this

process. It is unnecessary to enlarge upon this feature since high-vacuum practice is a well-known art in all physics laboratories today. The counter must also, of course, have the additional treatments which are necessary to correctly condition its electrodes. Rather than attempt to outline the mechanical construction in general terms, we shall indicate the principles by examples.

Stratosphere Counter.—A very useful type of small counter which illustrates most of the important points of construction has been designed by G. L. Locher.[5] Large numbers of these counters were made for the cosmic-ray observations in the three manned-balloon stratosphere flights for which the Bartol Research Foundation furnished apparatus, and they have proved to be entirely satisfactory in every way. Many of them, made in 1934, are still in use and perform very well. The detailed construction is indicated by the sketch shown in Fig. 3. The counter is constructed in a Nonex glass [6] envel-

FIG. 3.

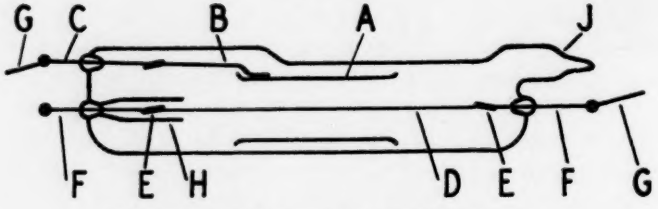


Diagram of a small counter, the "Stratosphere" type.

ope, and has a seamless copper cathode,[7] *A*, three centimeters long, one centimeter in diameter, and of material 0.010 inch thick, whose ends have been slightly flared out. The nickel wire, *B*, 0.040 inch in diameter, is silver soldered to the cathode and supports it away from contact with the glass. It is spot welded to the 0.030 inch tungsten lead, *C*, which is sealed directly through the nonex envelope. The counter wire, *D*, is tungsten,[8] 0.003 inch thick, spot welded through intermediate pieces of nickel, *E*, to the lead-in wires, *F*, which are sealed

[5] W. F. G. Swann and G. L. Locher, JOUR. FRANK. INST., **221**, 275 (1936).
[6] Nonex, No. 772 Glass, Corning Glass Co., Corning, N. Y.
[7] Improved Seamless Wire and Tube Co., Providence, R. I.
[8] Callite Products Co., Union City, New Jersey.

through the glass. Leads are brought out at both ends of the wire so that current may be passed through the wire to heat it during the cleaning process. Only one wire lead is necessary, of course, for the operation of the finished counter. The tungsten leads *C* and *F* are furnished with tails of many-stranded, twisted copper wire which are brazed on. The weld at the end of the counter wire (anode) which is brought out at the same end of the tube as is the cathode lead is covered by a glass shield, *H*, in order to prevent a discharge between *B* and any sharp point which might be present on the weld. The envelope is tubulated at *J* for sealing onto the vacuum system. During the blowing of the envelope the counter wire is stretched tightly. The thermal expansions of the tungsten and nonex glass are sufficiently similar so that this tension is maintained after the counter has cooled.

It is important to be sure that no part of the glass envelope is too close to the sensitive volume of the counter, since the glass will become charged and subsequently discharged, giving rise to spurious counts. Thus, for example, the shields *H*, Fig. 3, must not be made too long.

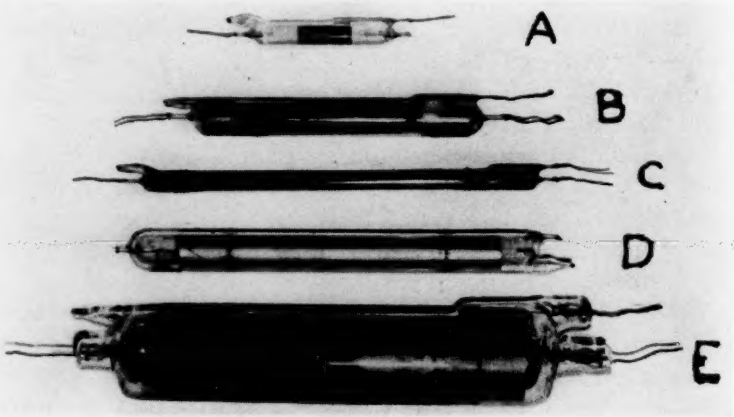
Other Types of Counters.—Counters of many other sizes have been successfully used, ranging from about ¼ to 7 cms. in diameter and from ½ to 50 cms. long. Other materials have also been used for the cathode and wire, but in general none are more satisfactory from all points of view, for cosmic and gamma ray counters, than tungsten wires and copper cylinders.

Figure 4 shows some of the types of counters which have been made and used. Counter *A*, Fig. 4, is the stratosphere type described above. Counters *B* and *C* have essentially the same construction as counter *A* except that the cathodes are too large to be supported entirely by the lead wire and rest upon the glass. The cathode may be furnished with external copper wires, silver soldered to it, to support it away from the glass envelope, as in counter *C*. It is advantageous to avoid contact between the glass and the cathode, so that it may be possible to allow cleaning agents to flow freely between them, and to be readily rinsed away after their use. Counter *D* is of the type designed by W. E. Ramsey [9] and has been used ex-

[9] W. E. Ramsey, *Phys. Rev.*, **57**, 1061 (1940).

tensively for studies of cosmic ray showers. Such counters are designed so that a group of them, placed in close contact, can cover a horizontal area, leaving the openings between the sensitive areas of the counters as small as possible. The glass envelopes are blown out and thinned to about ½ mm. thickness, and the cathodes are in close contact with the glass. This circumstance necessitates a special cleaning procedure which will be described below.

FIG. 4.



Five types of Geiger-Mueller counters.

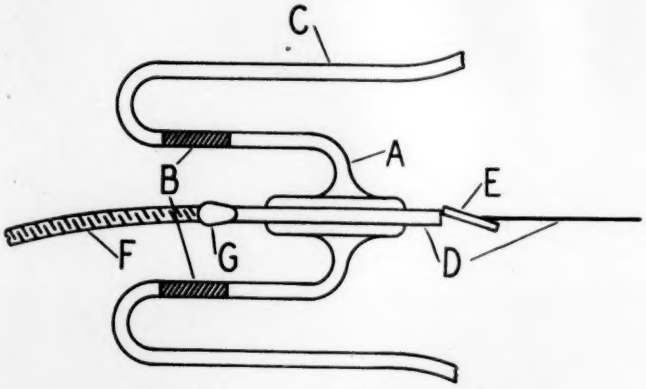
The four types of counter mentioned above are constructed of nonex glass. When counters of a larger size are to be made, one is faced with a new problem. Nonex glass is not particularly strong mechanically, and it is more desirable to use pyrex.[10] However, the coefficients of expansion of tungsten and pyrex are sufficiently different so that two difficulties arise. First, the counter wire will not be maintained at the correct tension. This may be remedied by including in the design a tungsten spring at one end of the wire. Second, and more serious, is the fact that tungsten-pyrex seals are not nearly as satisfactory as tungsten-nonex seals, and frequently crack.[11] It is, therefore, advisable to use nonex glass for the

[10] Pyrex No. 774 Glass, Corning Glass Co., Corning, N. Y.

[11] E. Vickers and C. P. Saylor, *Rev. Sci. Instr.*, **10**, 245 (1939).

tungsten seals, sealing the nonex to the pyrex with an intermediate glass.[12] Counter *E* in Fig. 4 is constructed in this manner. Figure 5 shows in more detail how such seals can be made.

FIG. 5.



Method of construction of Nonex-pyrex seals.

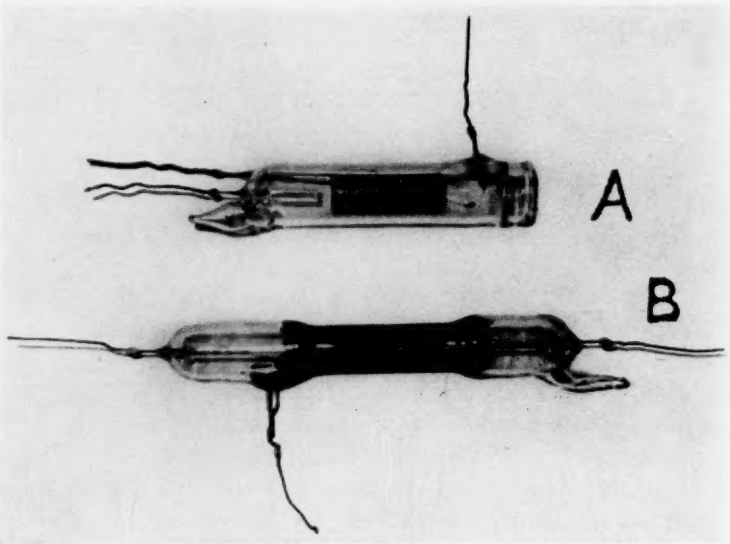
Special Forms of Counters for Alpha and Beta Rays.—In order to count ionizing particles whose ranges are small, such as the alpha and beta rays from radioactive substances, it is necessary to use a counter with a very thin window, to allow the passage of the rays into the counter. Figure 6 is a photograph of two counters designed for this special purpose. Counter *A* has a thin pyrex window blown on one end, concave outwards. Such a pyrex window can be made less than 0.0005 inch and still be strong enough to withstand the atmospheric pressure outside the counter, although it bends appreciably under stress. Such a thickness of glass is equivalent to only a few centimeters of air, and alpha particles can easily penetrate it and be recorded. The window offers almost a negligible stopping power for beta rays, and they can be counted without the necessity of applying to the results large corrections for absorption.

Counter *B*, Fig. 6, is of a type which can be used to measure beta rays coming from a large area. The glass of the central portion of the tube has been blown thin and can be made from 0.004 to 0.006 inch without becoming too weak to withstand

[12] Pyrex Blue Glass No. 542, Corning Glass Co., Corning, N. Y.

atmospheric pressure. This thickness corresponds to approximately 20 to 30 cms. of air, and can be readily penetrated by all but the least energetic beta particles. The glass at the ends of the tube is thicker and amounts to perhaps ¾ mm. The cathode of the counter shown was formed by painting a thin layer of Aquadag [13] (a colloidal suspension of carbon) on the inner surface of the glass. Cathodes may also be made by

FIG. 6.



Two types of counters which will allow the passage of charged particles into the counting volume. Counter *A* has a thin window at one end; in counter *B* the cathode consists of a layer of graphite on very thin glass.

sputtering or evaporating a thin layer of metal, such as gold or platinum, upon the glass. Such cathodes cannot be chemically cleaned, of course, and great care must be taken to avoid soiling them. Counters having this type of cathode sometimes, but not always, work better (have fewer spurious counts) if the *outside* of the thin glass portion is also coated with the conducting layer, which layer is maintained at the same electrical potential as the inner one.[14]

[13] Acheson Colloids Corporation, Port Huron, Michigan.

[14] No completely satisfactory explanation for this behavior has been advanced. G. L. Locher has suggested that the inner coating is not quite uniform and there

The Cleaning Process.—To achieve the desired chemical stability of a counter and to obtain surfaces of the electrodes which are uniform in composition, it is necessary to subject the counter to a cleaning process before it is filled with gas and sealed off. The counter should be washed with the following:

(*a*) Hot soapy water, followed by clean water.—The action may be improved by adding any of the commercial detergents.

(*b*) An acid solution whose constitution is not critical but may be 1 part 50 per cent. nitric acid, 1 part 90 per cent. sulphuric acid, 5 to 10 parts water. This acid should definitely attack the copper and will turn green or blue with use, from the dissolved copper salts. The intensity of its action will depend upon the amount of copper dissolved and the passivity of the copper cylinder. Its action may be hastened by gentle heating. The copper cylinder should be bright after this washing, but becomes oxydized very easily.

(*c*) Five to ten water baths. Any remaining acid may be neutralized by a weak solution of ammonia. Any salts left by this will vaporize later when the counter is heated. The last washing waters should be distilled.

The counters may now be dried and sealed to the pumps. The shower counters described above (counter *D*, Fig. 4) cannot be washed in this way and the parts must be carefully cleaned by this process before assembly. The counters should be pumped to a high vacuum, the pressure being not more than 10^{-5} mm. of mercury, and baked at about 350°–400° C. for a couple of hours at this high vacuum. The counter cylinders at this stage will be covered with a thin layer of oxide and appear dark. If the counters have not been sufficiently washed with water after the acid treatment, the glass walls may be discolored with copper oxide in either the red or the black form. This is to be avoided, but such discoloration will not greatly interfere with the action of the completed counter.

The subsequent procedure depends now upon the gas

are holes left which expose portions of the glass walls. These insulating surfaces may become charged in the operation of the counter and later discharged again, giving rise to spurious counts.

mixture which is desired. Counters which are to be filled with hydrogen or a mixture of hydrogen and a noble gas, should, of course, have the copper oxide removed and the cylinders bright. To accomplish this, hydrogen should be admitted to the system up to atmospheric pressure and the baking be continued until all the oxide is reduced. Commercial hydrogen may be used for this operation. If oxygen or air is to be used for the gas in the finished counter, the counter cylinders should be oxidized to a uniform state. Oxygen may be admitted to atmospheric pressure as the counters are allowed to cool in the furnace. The oxygen should be present for at least fifteen minutes while the temperature is above about 150° C. It sometimes seems to be desirable to bake the counter first in hydrogen and then in oxygen. This is especially true with counters which cannot be washed thoroughly. A properly oxidized copper cylinder has a characteristic uniform dark color which is easily recognized. Too much oxidation is to be avoided since particles of a thick layer of oxide may become detached from the cylinder. A bright copper cylinder should be so bright as to show the individual crystallite faces of the copper with their characteristic glitter.

After the oxidation or reduction process, the vacuum system should be pumped again to a high vacuum and the tungsten wire outgassed. A temperature of 1500° C. is sufficient to liberate the surface gas on tungsten and this is easily obtained by passing a current through the wire for a short time. A volume of gas, measured at atmospheric pressure, equal to three or four times the volume of the wire, and consisting mostly of carbon monoxide, is given off. Hence it is well to heat the wire several times, allowing the pumps to remove the gas between heatings. The total time of heating should be of the order of half a minute. It is desirable, although not absolutely necessary to heat the wire in this way. Besides removing the gas, the heating process will also remove the oxide coating of the wire. This is advantageous, since this coating is brittle and often cracks, possibly leaving a sharp point on the wire. However, many entirely satisfactory counters have been made without flashing the wire. Counter *C*, Fig. 4, is an example.

It is probably unnecessary to take extreme precautions to

avoid the presence of mercury vapor in the counters. Good counters have been made without using any cold traps on the mercury pumps so that they contained more than 10^{-3} mm. of mercury pressure. Indeed, it has been claimed that the presence of mercury reduces the number of spurious counts.[15] However, the use of cold traps is recommended since they do remove other, harmful, substances.

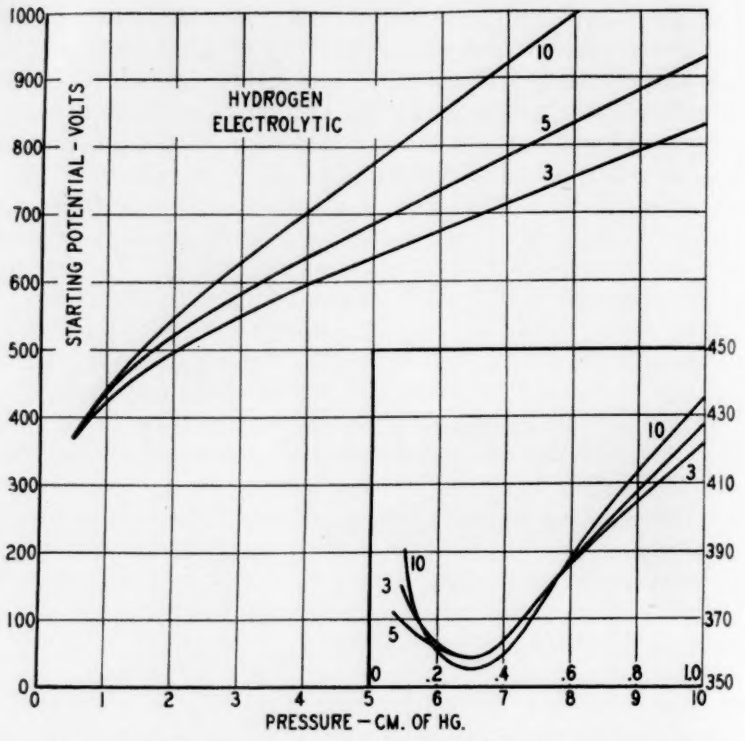
Filling the Counter.—The particular purpose for which the counter is to be used largely determines the nature and pressure of the gas with which the counter is to be filled. The gas filling determines, primarily, three things: the starting potential of the counter, the efficiency of the counter, and the magnitude of the time lags between the passage of the ionizing ray and an appreciable change of potential of the counter wire. The gas and pressure chosen must usually be determined as a compromise in the attainment of the most desirable characteristics.

The starting potential of a counter is not entirely determined by the radii of the wire and cathode and by the pressure and nature of the gas. The nature of the cathode surface has a small effect. However, for the purposes of design this cathode effect can generally be neglected, since it amounts to only a few volts. It is, therefore, worth while to present data showing the starting potentials for a particular counter filled with various gases. C. L. Haines[16] has published curves taken with the stratosphere type of counter described above, and Fig. 7 shows some of his results. For each variety of gas mixture there are shown three curves labeled 3, 5, and 10 which were measured with different wire sizes, of 0.003, 0.005, and 0.010 inch diameter. In each case, the diameter of the cylinder was 1 cm. Elementary considerations might suggest that, for a given gas, the starting potential would be a function only of the parameter E/p, where E is the electric field strength at the surface of the wire and p is the gas pressure. It is to be noted from Fig. 7 that this is *not* the case, and other factors must enter into the determination of the starting potentials. The potentials given in Fig. 7 actually correspond to voltages such as p' in Fig. 2.

[15] G. Medicus, *Zeits. f. Phys.* **103**, 76 (1936).

[16] C. L. Haines, *Rev. Sci. Inst.*, **7**, 411 (1936).

FIG. 7.



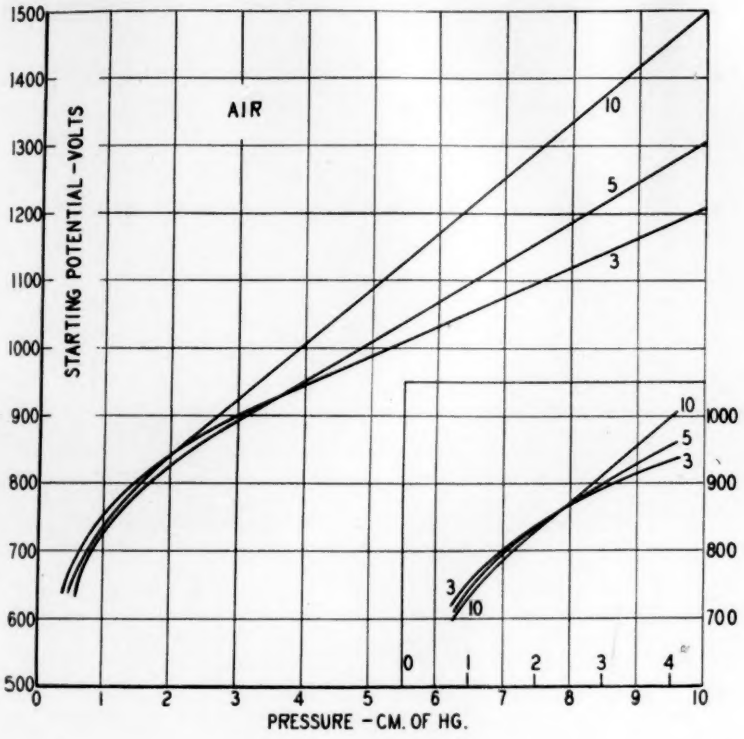
The starting potential of counters filled with various gases. The diameter of the cathode is one centimeter; the diameter of the wire is marked on the curves in thousandths of an inch.

Parts of Fig. 7 continued on following pages.

rather than to the potentials V_s which we have defined as the starting potential. However, for considerations of design, the differences are unimportant.

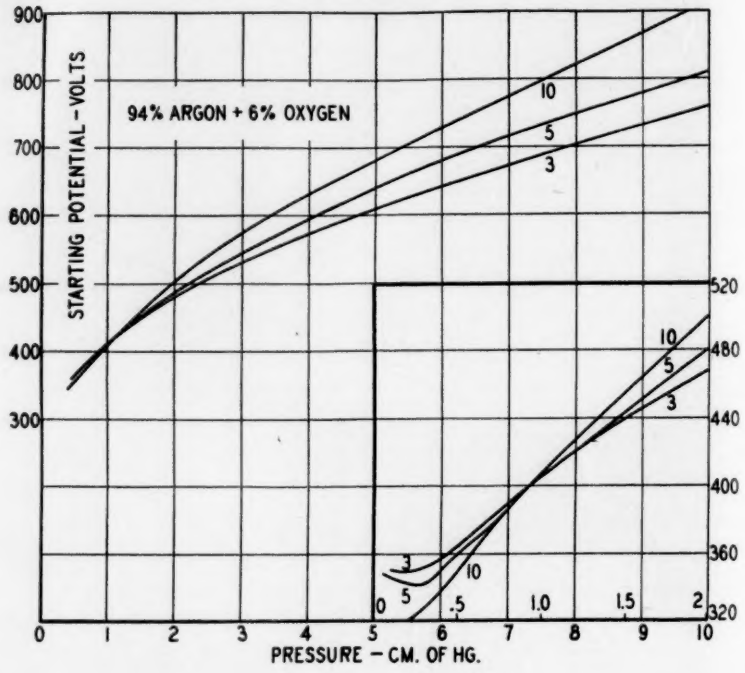
Other mixtures of gases are also suitable for use in counters. A mixture of 90 per cent. argon plus 10 per cent. hydrogen is particularly good. The starting potentials are lower than those of the argon-oxygen mixture shown in Fig. 7. For example, a counter with a 0.003 inch wire and a 1 cm. cylinder, filled with argon-hydrogen to a pressure of 18 cms., will start at about 740 volts. Similarly a mixture of argon and air may be used. In fact, in general, a mixture of a noble gas with a small proportion of air, hydrogen, or oxygen is suitable for a

FIG. 7—*Continued.*



counter. A pure noble gas will not work satisfactorily since metastable atoms are formed in the discharge which will diffuse to the walls of the tube, and cause the emission of electrons with a high probability and thus the production of spurious counts. The time of diffusion is of the order of 10^{-2} seconds and hence there will be no plateau at all in the counter characteristic. The addition of a second gas will cause the disappearance of these metastable atoms by means of collisions of the second kind, and their effect may be eliminated. Air, and nitrogen or oxygen alone are not very satisfactory gases. Nitrogen possesses metastable states although they are not as important as in the case of the noble gases. Counters filled with pure oxygen appear to be inefficient presumably because of electron capture. Not much information is available on

FIG. 7—*Continued.*

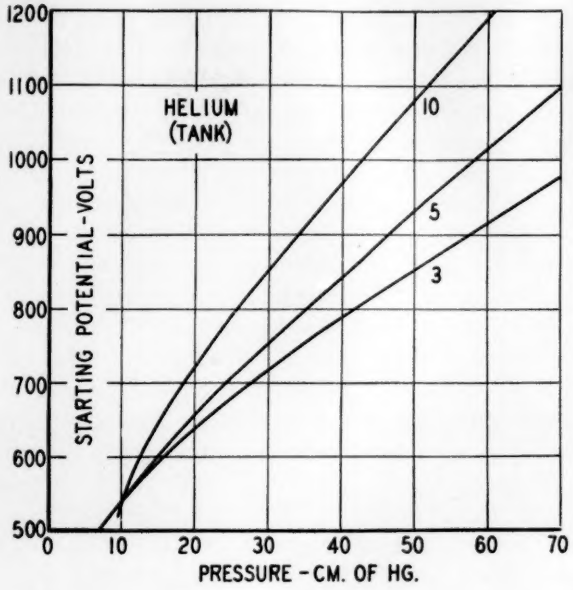


this point, since counters made with oxygen alone are not very satisfactory and have not been much used.

It should again be emphasized that, to attain the desired chemical stability, argon-oxygen mixtures should be used with oxide coated cathodes, while argon-hydrogen mixtures or pure hydrogen should be used with bright cylinders. For this reason also, air is unsatisfactory, since the nitrogen and oxygen can react under the conditions of a discharge. A number of workers following Trost [17] have prepared counters containing alcohol vapor, and attained thereby certain desirable features which we shall discuss below. However, the alcohol in such a counter will eventually be broken up in the discharge, and may also react with any copper oxide present. The counter characteristics will change with time and eventually the counter will become unsatisfactory.

[17] A. Trost, *Zeits. f. Phys.*, **105**, 399 (1937).

FIG. 7—*Continued.*



It should be pointed out here that the starting potential of a Geiger-Mueller counter has no intimate relation to the minimum potential which will support a steady glow discharge across the tube. While it is true that in counters filled, say, with an argon-oxygen mixture the two potentials are within 5 or 10 volts of each other, in alcohol counters the difference may be several hundreds of volts. The reasons for this will become evident in the discussion, to follow, of the counter discharge mechanism. The effect of the gas mixture used upon the counter efficiency and the occurrence of time lags can be discussed more profitably after we have considered these questions in a later section.

Concerning the actual operation of filling the counter, there is little to be said. The filling should be done slowly to avoid carrying dust into the counter. In filling with a mixture of gases, it is better to mix the gases first in the desired proportions, store them in a flask on the vacuum system, and fill the counters from this flask rather than mix the gases in the counter itself. If it is desired to mix alcohol vapor with the

counter gas, it is convenient to have a closed tube, containing alcohol, from which the air has been pumped out connected with a stop-cock to the vacuum system. Ethyl alcohol has a vapor pressure of 12.2 mm. at a temperature of 0° C., and this pressure of alcohol vapor can be added to the counter by immersing the tube containing the alcohol in melting ice and opening the stop-cock. A surprisingly long time, up to half an hour or more, may be necessary to allow the alcohol vapor to diffuse into the counters.

External Coating of the Counter.—After the counter has been sealed off from the pumps, there are still several operations which must be done to insure good performance. First, the copper leads should be tinned if they are to be soldered to anything. Since they may have acquired quite a heavy oxide coat during the baking of the counter this may be difficult. One method of procedure is the following: Heat the copper braid in a flame until it becomes red. Dip into solid ammonium chloride, making sure that plenty of the solid clings to the braid. Heat again in the flame until the chloride is almost removed. Dip the braid into soldering flux and immediately into a pot of molten solder. These operations may be carried out rapidly and usually give good results. Do not try to heat a half-tinned piece of copper in the flame to repeat the process. This will burn up the solder that is present, and make it almost impossible to tin the wire thereafter.

The second operation is to insure that the leakage resistance of the glass between the counter terminals is sufficient. Glass in humid weather is noticeably hygroscopic, and a surface layer of moisture will form which has a very low and variable resistance. To prevent this, a portion, at least, of the counter should be covered with a high-melting-point wax. Ceresin or the wax known as "Superla" [18] are well suited to the purpose. The wax may be applied either by dipping or painting, provided that the wax and the glass are hot enough to remove the water that is present on the glass before waxing.

It is sometimes desirable to provide the counter with additional electrical shielding. The central portion where the cylinder covers the wire is sufficiently well shielded by the

[18] Superla wax may be obtained from the Shallcross Manufacturing Co., Collingdale, Pa.

cylinder itself, but the ends of the wire are exposed. Such shielding may sometimes be conveniently done by painting that portion of the counter with aquadag which may then be connected as desired. Counter *D*, Fig. 4, has been treated in this way.

Occasionally a counter is made which is photoelectrically sensitive to light which can pass through the pyrex or nonex glass. This happens more often with bright copper cylinders than with oxidized ones. A coating of aquadag is good for eliminating this light. Another method is to use a fat-soluble red dye [19] dissolved in the wax which is applied for insulation.

[19] For example, Sudan IV, National Aniline and Chemical Co., N. Y.

(*To be continued.*)

Relation of Age to Industrial Injuries.—During the last twenty years workers have repeatedly voiced their objections to discrimination against older workers in management's hiring policies. One of the reasons cited in justification for this policy is that the older worker is more of an accident risk than is the younger worker. In substantiation, it has been contended, first that the physiological changes which accompany age decrease the speed of the older worker's reaction to danger, thus increasing his chances of getting hurt; and second, that once injured, his chances of recovery without permanent impairment are less and that his period of recovery is longer than for the younger worker. An attempt to evaluate these contentions is made in an article in the *Monthly Labor Review*, Volume 51, No. 4, by Max D. Kossoris. It shows that older workers were injured less frequently than younger workers; but once injured they experienced proportionately more deaths and permanent impairments than did younger workers. Similarly, their healing periods in temporary disability were, on the average, longer. Available surveys in this field are analyzed in detail. They include four plants—two of them public utilities, one a light manufacturing, and another a heavy manufacturing company; industrial injuries reported to the Wisconsin Industrial Commission; experiences in Switzerland and Austria; and the New York State Department of Labor. Mr. Kossoris points out that the data cited are not to be interpreted as showing that injuries to older workers are, on the average, more costly to an employer than those to younger workers. It is an open question, still be be verified by study, whether the less frequent but more severe injuries to older workers are more or less costly than the more frequent but less severe injuries to younger workers.

R. H. O.

Radio Frequency Allocations.—The R. C. A. Laboratories have recently published a very interesting and useful chart on radio frequency allocations as of January 1, 1941. It is arranged in the form of columns, three in number, showing allocations in kilocycles in accordance with the General Radio regulations (Cairo revision 1938), European allocation (Cairo revision 1938), and the Inter-American Allocation (Santiago revision 1940). The columns are divided into colors showing the type of services and the frequencies to which each is assigned. There are some 20 different services in all. In addition there are some 40 notes, numbered along the columns which point out special features of certain allocations. The chart permits quick reference to any type of radio service and frequency and the source from which allocations originate.

R. H. O.

NOTE ON THE KEEPING OF HYDROGEN PEROXIDE-AMMONIA HYPO ELIMINATOR SOLUTIONS.

In connection with the preparation and use of the hydrogen peroxide-ammonia hypo eliminator solutions described in the December issue of the JOURNAL, it is important to realize that such solutions give off oxygen continuously, but, in spite of this decomposition, they possess a satisfactory exhaustion life. However, *the mixtures must not be stored in closed containers at any time.* The hypo eliminator solution should be mixed just before use and kept in open containers until discarded.

When storing the 3 per cent. hydrogen peroxide solution used for preparing the hypo eliminator solution, the following precautions should also be taken:

(1) The solution should be stored in a brown bottle away from daylight and in a cool place since both heat and light accelerate the decomposition of hydrogen peroxide.

(2) An ordinary loose-fitting cork rather than a screw cap type of stopper should be used.

(3) If the bottle is large, a small-bore glass tube should be inserted through the cork to permit the oxygen gas to escape and thus to avoid the possibility of pressure being developed, resulting in bursting of the bottle.

(4) Large-scale users should consult with the chemical manufacturers on precautions in handling and storing hydrogen peroxide solutions.

["The Elimination of Hypo from Photographic Images," by J. I. Crabtree, G. T. Eaton, and L. E. Muehler. Published: JOUR. FRANK. INST., **230**: 701–35, December, 1940.]

Model Tests Showed Aerodynamic Instability of Tacoma Narrows Bridge.—M. A. BOWERS (*Engineering News Record*, Vol. 125, No. 21). Wrecking of the 2,800 ft. highway suspension span over Tacoma Narrows near Tacoma, Wash., by cumulative undulation and twisting on November 7, last, was the final chapter in a story of alarming unsteadiness and attempts to find means of preventing or controlling the snake-like movements of the bridge. Even before construction of the steel towers was completed rumors of small undulations of the Whitestone Bridge at New York had led the engineers to decide on elaborate tests on an elastic model of the Tacoma structure. These tests, carried on by Prof. F. B. Farquharson of the University of Washington during the past summer, showed satisfactory control to be difficult. Finally, wind tunnel tests on models of the deck revealed conditions of aerodynamic instability believed sufficient to set up oscillations of the kind that proved destructive, and plans had been made for streamlining (fairing) or else shielding the sides of the stiffening girders. Collapse came while a decision was pending. It is not known whether failure began in the suspender cables or in the girders or floor. A decided disalignment of the stiffening girder at midspan appears in a picture taken at a time when the concrete roadway had not yet begun to fall. Another picture, taken soon after the first concrete fell, shows a panel of lateral bracing broken loose and hanging down below the floor. The suspender connections apparently did not fail, as breaks occurred consistently in the ropes themselves. Frayed stranded ends swinging in the wind show the breaks occurred in different locations, and such examination as has been possible indicates that only one of the many broken suspenders has the socket still attached. The main cables show no damage that can be seen from a distance.

R. H. O.

The Electron Microscope.—On Thursday, April 17, MR. JAMES HILLIER of the R. C. A. Laboratories addressed members and guests of the Philadelphia Section, American Chemical Society on the construction, operation, and practical applications of the electron microscope.

Magnification, obtainable with ordinary microscopes using visible or ultraviolet light, is limited to about 3000 diameters. The new electron microscope, however, is capable of approximately 100 times greater magnification. This instrument utilizes principles similar to those employed in optical microscopes except that magnetic electron lenses replace glass lenses. A stream of high velocity electrons replace light waves.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

REVISED STANDARD FREQUENCY BROADCASTS.

Immediately after the Bureau's standard frequency station, WWV, was destroyed by fire on November 6, 1940, (Technical News Bulletin 284 (December, 1940)), a transmitter was established in another building and partial service was begun. The service has now been extended, although still with temporary equipment. Except for possible breakdowns, it will be on the air continuously at all times day and night, and carries the standard musical pitch and time intervals. The radio frequency is, as before, 5 megacycles (= 5,000 kilocycles = 5,000,000 cycles) per second.

The standard musical pitch is the frequency 440 cycles per second, corresponding to A above middle C. In addition there is a pulse every second, heard as a faint tick when listening to the 440 cycles. The pulse lasts 0.005 second and provides an accurate time interval.

The 440-cycle tone is interrupted every five minutes for one minute, to give the station announcement (WWV in telegraphic code) and to provide an interval for checking radio measurements.

The accuracy of the 5-megacycle frequency, and of the 440-cycle standard pitch as transmitted, is better than a part in 10,000,000. Transmission effects in the medium (Doppler effect, etc.) may result in slight fluctuations in the 440-cycle frequency as received at a particular place; the average frequency received is however as accurate as that transmitted. The time interval marked by the pulse every second is accurate to 0.00001 second. The 1-minute, 4-minute, and 5-minute intervals marked by the beginning and ending of the announcement periods are accurate to a part in 10,000,000. The beginnings of the announcement periods

* Communicated by the Director.

are so synchronized with the basic time service of the U. S. Naval Observatory that they mark accurately the hour and the successive 5-minute periods; this adjustment does not have the extreme accuracy of the time intervals, but is within a small fraction of a second.

The broadcast is from a 1-kilowatt transmitter. It is most useful for moderate distances in the daytime and long distances at night. For reception in locations reasonably free from interference, it is receivable in the summer at all distances up to about 500 miles from Washington in the middle of the day. The distance range increases after about 4 P.M. (E.S.T.) until at night the broadcast is receivable throughout the United States (i.e., the 5-Mc carrier frequency; the 440-cycle tone is sometimes not receivable at night beyond about 1300 miles). Sometimes at night it may be difficult to receive either the 5 Mc or the 440 cycles at distances between about 50 and 500 miles, while it is easy to receive them beyond 500 miles. In the autumn the daytime distance range will increase, rising to about 1000 miles in the winter.

The service from the temporary transmitter will continue until the Bureau can establish a new station to provide, more fully than in the past, standard frequencies reliably receivable at all times throughout the country. These will be transmitted on more adequate power, and several radio carrier frequencies will be used, in order to provide more certain coverage of all distances and times.

PROTECTION OF DOCUMENTS WITH CELLULOSE ACETATE SHEETING.

The lamination of paper with cellulose acetate sheeting, a process developed at the Bureau for the protection of documentary material, is being quite extensively practiced. A further investigation has now been made to ascertain the quality of the sheetings being used by different operators and the efficacy of their processes.

Identical papers representing the types generally used for documents were sent to six commercial concerns and The National Archives of the United States, who laminated the papers with sheeting and returned them, together with

samples of the sheeting used, to the Bureau for test. It was found that three of the operators used plain sheeting and applied it to the papers with heat and pressure, one used sheeting coated with an adhesive and also applied it with heat and pressure, and the others used sheeting containing an adhesive but applied it with pressure only. The sheetings represented the products of three manufacturers who make special types for the purpose.

The sheetings were tested for chemical and physical properties which are related to laminating quality, resistance to wear, and stability. They were all found to be very satisfactory. They had high strength and were apparently as stable as the best grade of papers made for permanent records.

The workmanship of the laminated papers was good. The sheetings were applied smoothly and they could not be removed without splitting the papers. Tests showed that the stability of the papers had not been adversely affected. To obtain indications of the permanence of the bond, the samples were subjected to extreme changes in moisture content and were baked at a high temperature. The bond of nearly all of them remained intact under the varied changes in moisture content. When the samples were heated for 72 hours at 100° C., the bond was loosened in many cases, but the fact that a large number remained unaffected by this severe treatment is evidence that a very high degree of stability of the bond can be attained. The sheeting of many of the samples yellowed somewhat under the heat test but the majority were not affected by this streatment.

In addition to its high strength and stability, the acetate sheeting is transparent, thin, easily cleaned with water, and is resistant to insects. Furthermore, the laminating process is speedy and is excellent for mending documents.

The complete report of this investigation has just been released as Miscellaneous Publication M168. The price is 5 cents.

SOLAR HEATING OF VARIOUS SURFACES.

As one phase of its low cost housing research, the Bureau has studied protection against summer heat. The present

concept of a low-cost house precludes the use of mechanical air cooling or dehumidifying devices on account of their cost. Instead, means for maintaining summer comfort must be restricted to insulating the ceiling or roof, using adequate shading devices for windows, and selecting paints and surface coverings which reflect most of the sunlight and tend to remain cool.

Building Materials and Structures Report, BMS64, just released by the Bureau, contains the results of a study of the reflective properties of house paints and surface coverings. Panels covered with white paints were found to be coolest and one covered with lamp black, the warmest when exposed to the sun. Paints of other colors were found to be intermediate between white and black in the protection they afforded against solar heat. Surfaces covered with light shades of paints, such as those commonly used for walls, were found to be only somewhat warmer than those covered with white paints, but a dark trim color was found to be nearly as warm as the black surface.

Copies of BMS64 are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents each.

MANOMETRIC GAS ANALYSIS APPARATUS.

In the April number of the *Journal of Research* (RP1380), Martin Shepherd and E. O. Sperling describe apparatus designed for the analysis of gas mixtures under the following conditions: (1) When the volume of the sample is small—of the magnitude of 5 to 0.5 ml.—and a reasonably accurate analysis is desired; (2) when the volume of the sample is of the order of magnitude of 0.2 to 0.1 ml., and an approximate microanalysis is desired; and (3) when the gases to be analyzed are dissolved in some liquid from which they must be liberated prior to analysis, as in the analysis of blood gases.

The apparatus is adapted for use with the admirable procedures of Van Slyke. The present design eliminates the two principal errors inherent in the Van Slyke apparatus, as well as the mechanical shaking which some have found to be

an objectionable feature. By extending the apparatus here described, analysis by combustion may be performed, and greater operating conveniences achieved if desired.

FREEZING TEMPERATURE OF IRONS AND STEELS.

The wide variety of purposes for which irons and steels are used makes their properties of the greatest importance. Furthermore, numerous alloys with special properties are required to satisfy the needs of modern industry. It is for this reason that the effect of various impurities and alloying elements upon the properties of iron is of such great interest. The effect of such constituents upon any property of pure iron can be established only after the value of that particular property has been determined. One property, which is of particular interest to those investigating or producing iron or steel, is the melting or freezing point.

The freezing temperature of high-purity iron (99.99 + per cent.) in an atmosphere of helium was recently measured by W. F. Roeser and H. T. Wensel, using an optical pyrometer, and found to be 1539° C. ± 1°. The same samples of iron were found to freeze 1° C. lower in an atmosphere of hydrogen. In addition, the initial freezing temperatures of some irons of lesser purity and of some steels were measured in an atmosphere of helium to determine the effects of various impurities and alloying elements. The results of measurements on 23 samples of irons and steels, together with the chemical analyses, are reported in RP1375 in the April *Journal of Research*. The freezing point depressions of the various elements are listed in a table which may be used to calculate the initial freezing temperatures (liquidus points) of iron or steel containing many combinations of 17 elements, which include all those generally found in commercial irons and steels.

The samples containing less than 0.1 per cent. of impurities were melted in beryllium oxide crucibles and the other samples, in all but two cases, were melted in crucibles of aluminum oxide. Temperatures were determined by means of an optical pyrometer sighted into refractory blackbodies immersed in the freezing metal.

TABLES OF SINE, COSINE AND EXPONENTIAL INTEGRALS.

A new volume of mathematical tables bearing the above title has been made available through the Bureau, which is acting as sponsor for a project conducted by the Federal Works Agency, Work Projects Administration for the City of New York. The volume is bound in buckram and contains 470 pages. The price is $2.00. Remittances should be made payable to and sent to the National Bureau of Standards, Washington, D. C. Payment in advance is required.

The functions tabulated in this volume, which are given to 9 places of decimals from 0 to 2 at intervals of 0.0001, are encountered in many fields of pure and applied mathematics. In the bibliography, references are given to papers in which these functions have been applied to the solution of problems in electrical engineering, chemistry, physics and biology. They have been selected primarily to show the variety of applications of these functions and to indicate the great frequency with which they occur in recent publications. A short list of reference texts and of the best-known tables of these functions, previously published by other authorities, is included.

THE FRANKLIN INSTITUTE.

STATED MONTHLY MEETING, APRIL 16, 1941.

The stated monthly meeting for April was held on the evening of Wednesday, April sixteenth, at eight-fifteen o'clock. Dr. Henry Butler Allen, Secretary, presided in the absence of the President, who was away because of illness.

The minutes of the previous meeting were approved as printed in the April issue of the JOURNAL.

The Secretary reported the following additions to membership:

Sustaining	1
Active	3
Associate	10
Student	27
Total	41

He then called the attention of the membership to Medal Day, which this year will be held on Wednesday, May twenty-first, at three-thirty d.s.t., in the afternoon. This will be the regular monthly meeting for May. Dr. Allen then gave a short summary of the programme for that day, giving a list of the Medals to be awarded and the names of the recipients, and pointed out that aside from the Franklin Medals, the presentation of a Cresson Medal to the United States Navy would undoubtedly command a great deal of interest. He urged all members and their friends to attend the afternoon ceremonies, as well as the Medal Day Dinner, given in honor of the medalists of the afternoon, at seven-thirty the same evening. He then called upon Dr. Barnes, who gave an outline of the very attractive programme which has been arranged for the dinner in the evening.

Dr. Allen then gave a brief resumé of the history of the Bartol Research Foundation of The Franklin Institute, stating that it was established by the bequest of the late Henry W. Bartol in 1922, for the maintenance of research in the physical sciences and especially in electricity and in problems of a scientific character growing out of industry.

He then introduced the speaker of the evening, Dr. W. F. G. Swann, Director of the Bartol Research Foundation of The Franklin Institute, who gave a report on this important and interesting work of the Institute. Dr. Swann's talk was accompanied by many demonstrations to illustrate the work which is being done. The paper has been written up in detail and will appear in an early number of the JOURNAL.

The presiding officer dismissed the meeting with a rising vote of thanks, after which many of the audience investigated the exhibits and talked individually with the lecturer.

HENRY BUTLER ALLEN,
Secretary.

LIBRARY NOTES.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is forty cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays two until ten o'clock P.M.

RECENT ADDITIONS.

AERONAUTICS.

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BERNHARD, HUBERT J., DOROTHY A. BENNETT, AND HUGH S. RICE. New Handbook of the Heavens. 1941.

JONES, H. SPENCER. Life on Other Worlds. 1940.

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COUSINS, FRED M. Analytical Design of High Speed Internal Combustion Engines. 1941.

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WILSON, PERRY W. The Biochemistry of Symbiotic Nitrogen Fixation. 1940.

CHEMISTRY AND CHEMICAL TECHNOLOGY.

BERKMAN, SOPHIA, JACQUE C. MORRELL, AND GUSTAV EGLOFF. Catalysis, Inorganic and Organic. 1940.

Institution of the Rubber Industry. Annual Report on the Progress of Rubber Technology. Volumes 2 and 3. 1938–1939.

LANGE, OTTO. Technik der Emulsionen. 1929.

PATTERSON, AUSTIN M., AND LEONARD T. CAPELL. The Ring Index. 1940. American Chemical Society. Monograph Series no. 84.

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HAMMOND, JOHN WINTHROP. Men and Volts. 1941.

VINAL, GEORGE WOOD. Storage Batteries. Third Edition. 1940.

ENGINEERING.

BISHOP, CARLTON THOMAS. Structural Drafting. 1941.

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JAKOSKY, J. J. Exploration Geophysics. 1940.

SCHUCHERT, CHARLES, AND CARL O. DUNBAR. A Textbook of Geology. Part 2: Historical Geology. Fourth Edition. Largely Rewritten. 1941.

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PICKELS, GEORGE W. Drainage and Flood-Control Engineering. Second Edition. 1941.

MATHEMATICS.

ALLEN, EDWARD S. Six-Place Tables. Sixth Edition. 1941.

METEOROLOGY.

PISTON, DONALD S. Meteorology. Second Edition. 1941.

MILITARY ENGINEERING.

HESSEL, F. A., M. S. HESSEL, AND WELLFORD MARTIN. Chemistry in Warfare, 1940.

HOWE, JAMES VIRGIL. Modern Gunsmith. Supplement. 1941.

MINING AND METALLURGY.

BRAY, JOHN L. Non-Ferrous Production Metallurgy. 1941.

LEWIS, ROBERT S. Elements of Mining. Second Edition. 1941.

PHOTOGRAPHY AND PRINTING.

NICHOLSON, DONALD. Photo-Offset Lithography. 1941.

PHYSICS.

JEANS, SIR JAMES. An Introduction to the Kinetic Theory of Gases. No date.

STOEVER, HERMAN J. Applied Heat Transmission. First Edition. 1941.

SANITARY ENGINEERING.

London, Metropolitan Water Board. Thirty-sixth Annual Report for the Year Ended 31st March 1939.

SCIENTIFIC ESSAYS.

COLLINS, A. FREDERICK. Science on Parade. 1940.

STATISTICS.

MIGONE, RAUL C. Interamerican Statistical Yearbook. 1940.

FINANCIAL STATEMENTS

as of December 31, 1940.

To the Board of Managers of
The Franklin Institute,
Philadelphia.

We have examined the balance sheet of THE FRANKLIN INSTITUTE as of December 31, 1940, and the statements of income and expenses and general fund for the year then ended, and, without making a detailed audit of the transactions, have examined or tested accounting records of the Institute and other supporting evidence.

The income as reported in the accompanying statement of income and expenses is stated from the books of account. We did not verify the income from the Museum aggregating $72,778.23 as it is not susceptible of independent verification. The expenses were supported by proper vouchers. The buildings and equipment and investments are stated at cost or appraised values at date of acquisition, and do not purport to represent present day values. We did not, at the request of the controller, mail to debtors requests for confirmation of the uncollected balances of accounts receivable as of December 31, 1940.

Based upon the statement of income as set forth in the preceding paragraph, the stating of investments at cost or appraised values at dates of acquisition, and subject to confirmation of accounts receivable balances by debtors, in our opinion, the accompanying financial statements present fairly the position of The Franklin Institute at December 31, 1940, and the results of its operations for the calendar year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

LYBRAND, ROSS BROS. & MONTGOMERY.

Philadelphia, Penna.,
April 21, 1941.

THE FRANKLIN INSTITUTE.

BALANCE SHEET, DECEMBER 31, 1940.

Assets.

Demand deposits in banks and cash on hand (not including cash in endowment trust funds)		$17,601.62
Accounts receivable:		
For memberships, subscriptions, exhibits, etc.	$4,571.42	
Due from officers and employees	938.14	
Due from income of trust funds (including amounts aggregating $2,983.87 not currently available)	3,249.14	
		8,758.70
Materials and supplies, at cost		9,374.22
Buildings and equipment, at cost, not including exhibits loaned and donated		4,097,955.04
		$4,133,689.58
Endowment fund investments, cash, etc.:		
Investments, at cost or appraised values at the dates of acquisition	$1,725,365.89	
Deposit in closed bank, less reserve	67,500.00	
Cash:		
Uninvested principal	26,857.82	
Unexpended income	7,463.06	
		1,827,186.77
		$5,960,876.35

Liabilities.

Accounts payable		$ 8,618.73
Deferred income from dues, donations, etc.		33,851.80
Contributed funds used for buildings, equipment, etc., as annexed		3,932,435.23
Stock outstanding:		
First class	$12,840.00	
Second class	70.00	
		12,910.00
General Fund account, as annexed		145,873.82
		$4,133,689.58
Endowment funds:		
Principal (see summary annexed)	$1,819,723.71	
Unexpended income	7,463.06	
		1,827,186.77
		$5,960,876.35

GENERAL FUND ACCOUNT

for the year ended December 31, 1940.

Balance, January 1, 1940	$151,539.67
Add:	
Amount withdrawn from the Museum Reserve Fund Principal for capital and operating expenditures	78,322.56
	$229,862.23
Less deficit for the year ended December 31, 1940	83,988.41
Balance, December 31, 1940	$145,873.82

INCOME AND EXPENSE ACCOUNT

for the year ended December 31, 1940.

Income.

Dues (prorated portion of annual dues), fees, etc.		$24,208.00
Less dues uncollected, prior years		187.00
		$24,021.00
Museum income:		
Museum admissions	$26,965.85	
Planetarium admissions	22,933.80	
Traveling shows, sale of guide books, etc.	22,878.58	
		72,778.23
Subscriptions to publications and advertising		6,769.52
Donations:		
Friends of Franklin	$31,904.17	
Less expenses	5,519.11	
		26,385.06
Administrative charges for services rendered The Bartol Research Foundation and The Biochemical Research Foundation		10,000.00
Miscellaneous income, net		954.60
		$140,908.41
Income from trust fund investments and distributions from estates, etc.		72,598.21
Income (*Carried Forward*)		$213,506.62

INCOME AND EXPENSE ACCOUNT (*Continued*)

Income (*Brought Forward*)			$213,506.62
Expenses.			
	Salaries and Wages.	Other.	
Building operation and maintenance	$38,738.77	$31,548.19	
Library	14,402.97	4,252.60	
Meetings	—	1,641.70	
Office and general	52,001.83	11,177.59	
Machine shop	733.60	257.18	
Museum	97,776.86	32,698.07	
Publications	—	12,838.51	
Science and The Arts	3,839.99	241.74	
Traveling expense	—	1,070.69	
Annuities	3,125.00	—	
Membership badges, certificates, etc.	—	118.16	
	$210,619.02	$95,844.43	
	$306,463.45		
Less donations received for museum salaries and expenses	8,968.42		
			297,495.03
Deficit for the year			$ 83,988.41

SUMMARY OF CHANGES IN ENDOWMENT FUNDS

for the year ended December 31, 1940.

Balances, January 1, 1940			$2,257,827.64
Add:			
Amounts received from:			
Estate of Annie M. Peale	$525.90		
Estate of Augene P. Rogers	746.62		
		$1,272.52	
Miscellaneous		5.78	
			1,278.30
Total (*Carried Forward*)			$2,259,105.94

SUMMARY OF CHANGES IN ENDOWMENT FUNDS (*Continued*)

Total (*Brought Forward*)		$2,259,105.94
Deduct:		
Reduction of ledger values of investments upon exchange of such investments under plans of reorganization	$347,338.45	
Losses, net of profits, on disposal of investments:		
Losses $16,378.48		
Profits 3,340.40	13,038.08	
Amounts withdrawn from Museum Reserve Fund for capital and operating expenditures including $3,322.56 transferred from principal of John G. Meigs Bequest	78,322.56	
Amounts representing distributions from principal of the John G. Meigs Bequest, transferred to income account, net	683.14	
		439,382.23
Balances, December 31, 1940		$1,819,723.71

CONTRIBUTED FUNDS RECEIVED FROM BENJAMIN FRANKLIN MEMORIAL, INC.,

for the year ended December 31, 1940.

Balance, January 1, 1940	$3,930,707.51
Add:	
Pledges collected	1,727.72
Balance, December 31, 1940	$3,932,435.23

THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE.

CONDENSED FINANCIAL REPORT

as of September 30, 1940.

To the Board of Managers of
The Franklin Institute,
Philadelphia.

We have examined the balance sheet of THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE as of September 30, 1940, and the statement of income and expenses for the fiscal year then ended, have reviewed the system of internal control and the accounting procedures of the Foundation and, without making a detailed audit of the transactions, have examined or tested accounting records of the Foundation and other supporting evidence, by methods and to the extent we deemed appropriate.

The laboratory building, which is located on the property of Swarthmore College, and the equipment are stated at cost and the investments at cost or appraisal values at dates of acquisition and do not purport to represent present day values. No allowances are provided for depreciation of the laboratory building and the greater portion of its equipment. The cost of books and scientific literature is charged to expense.

In our opinion, the accompanying balance sheet and related statement of income and expenses, present fairly, the position of The Bartol Research Foundation of The Franklin Institute at September 30, 1940, and the results of its operations for the fiscal year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year, except in so far as the position of the Foundation at September 30, 1940, and the results of its operations for the fiscal year may be affected by the market value of the trust investments and by the failure to provide for depreciation of the laboratory building and equipment.

LYBRAND, ROSS BROS. & MONTGOMERY.

Philadelphia, Penna.,
April 21, 1941.

THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE.

BALANCE SHEET, SEPTEMBER 30, 1940.

Assets.

Cash:			
Demand deposit in bank and cash on hand, general fund		$3,317.09	
Unexpended income:			
Henry W. Bartol Bequest	$5,492.46		
Investment of unexpended income fund	12,723.62	18,216.08	
			$ 21,533.17
Investments of unexpended income fund, at cost			223,876.21
Accounts receivable			198.70
Building and equipment, at cost:			
Laboratory building		$226,591.05	
Furniture and fixtures		14,971.54	
Equipment:			
Laboratory	$87,988.69		
Less allowance for depreciation	8,123.79	79,864.90	
Machine shop	$16,862.69		
Less allowance for depreciation	2,168.51	14,694.18	
Building		375.00	
Office		3,013.47	
Library		1,057.65	
			340,567.79
			$586,175.87

Investments (at cost or appraised values at dates of acquisition) and cash composing principal of trust funds:

	Investments.	Cash.	
Henry W. Bartol Bequest	$1,298,585.51	$20,515.57	
Pension fund	82,786.09	1,455.05	
	$1,381,371.60	$21,970.62	
			1,403,342.22
Assets (*Carried Forward*)			$1,989,518.09

BALANCE SHEET, SEPTEMBER 30, 1940 (*Continued*)

Assets (*Brought Forward*)			$1,989,518.09
Collateral Trusts.			
Cash:			
Uninvested principal	$3,502.20		
Undistributed income	3,041.97		
		$6,544.17	
Investments (at cost or appraised values at dates of acquisition):			
Helene Bonar Bartol Trust	$296,211.42		
Lucy Cheyney Farr Trust	152,034.30		
Katherine de Monclos Trust	151,877.61	600,123.33	
			606,667.50
			$2,596,185.59
Liabilities.			
Accounts payable			$2,008.05
General Fund account:			
Balance, October 1, 1939		$578,648.50	
Excess of income over expenses for the year ended September 30, 1940, as annexed		5,519.32	
Balance, September 30, 1940			584,167.82
			$586,175.87
Endowment Funds:			
Henry W. Bartol Bequest		$1,319,101.08	
Pension fund		84,241.14	
			1,403,342.22
			$1,989,518.09
Collateral Trusts.			
Principal:			
Helene Bonar Bartol Trust	$299,506.94		
Lucy Cheyney Farr Trust	152,159.36		
Katherine de Monclos Trust	151,959.23		
		$603,625.53	
Undistributed income		3,041.97	
			606,667.50
			$2,596,185.59

STATEMENT OF INCOME AND EXPENSES

for the fiscal year ended September 30, 1940.

Income

Income received from investments		$61,566.23

Expenses.

	Salaries and Wages.	Other.	
Building operation and maintenance	$1,100.00	$3,050.55	
Library	—	416.47	
Administrative and general	15,200.00	2,177.44	
Laboratory and machine shop	25,258.43	3,500.09*	
Publications, reprints	—	537.96	
Traveling and entertainment	—	115.15	
Administrative charge, The Franklin Institute	—	5,000.00	
	$41,558.43	$14,797.66	
			56,356.09
			$ 5,210.14
Other income:			
Profit, net of loss, on the sale of income investments			309.18
Excess of income over expenses for the year, transferred to General Fund Account			$ 5,519.32

* Includes provision of $949.20 for depreciation of laboratory equipment.

THE BIOCHEMICAL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE.

CONDENSED FINANCIAL REPORT

as of August 31, 1940.

To the Board of Managers of
The Franklin Institute,
Philadelphia.

We have examined the balance sheet of THE BIOCHEMICAL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE as of August 31, 1940, and the statements of expenses and income and the general fund account for the fiscal year then ended, have reviewed the system of internal control and the accounting procedures of the Foundation and, without making a detailed audit of the transactions, have examined or tested accounting records of the Foundation and other supporting evidence, by methods and to the extent we deemed appropriate.

The research apparatus and other equipment are stated at their appraised values on July 1, 1935, with additions since that date at cost, including improvements having a ledger value of $11,461.75, made to leased property vacated by the Foundation subsequent to August 31, 1940. No allowances are provided for depreciation of the laboratory equipment or for amortization of improvements having a ledger value of $11,461.75 made to leased property.

In our opinion, the accompanying balance sheet and the related statements of expenses and income and general fund account present fairly the position of The Biochemical Research Foundation of The Franklin Institute at August 31, 1940, and the results of its operations for the fiscal year, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year, except in so far as the position of the Foundation at August 31, 1940, and the results of its operations for the fiscal year may be affected by the failure to provide depreciation of the laboratory equipment and amortization of certain improvements to leased property.

LYBRAND, ROSS BROS. & MONTGOMERY.

Philadelphia, Penna.
April 21, 1941.

THE BIOCHEMICAL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE.

BALANCE SHEET, AUGUST 31, 1940.

Assets.

Cash:			
Demand deposits in bank and cash on hand		$4,485.13	
Unexpended cash of funds available for current operations:			
Biochemical Research Foundation	$6,268.09		
Emma M. Schaible Bequest	1,786.60	8,054.69	
Unexpended cash funds available for bonuses to employees (see contra)		22,270.15	
Unexpended cash available for construction of laboratory building:			
Demand deposits in bank	$33,309.75		
Time deposit in bank	79,554.43	112,864.18	
			$147,674.15
Investments, at appraised values at dates of acquisition:			
Biochemical Research Foundation		$152,305.00	
Emma M. Schaible Bequest		1,573.00	
			153,878.00
Land, laboratory building and equipment:			
Land, donated, at nominal value		$1.00	
Laboratory building under construction, at cost (see Note A)		95,310.00	
Equipment, at appraised value July 1, 1935, with subsequent additions at cost:			
Research apparatus and equipment		143,342.69	
Improvements to leased property (less provision of $750.69 for amortization) (see Note B)		11,680.15	
Cyclotron experiment		23,976.26	
Library books		6,112.02	
			280,422.12
			$581,974.27

Liabilities.

Accounts payable:		
Due under contract for construction of building (see Note A)	$37,119.75	
Other	3,614.01	
		$40,733.76
Unexpended income from investments, available for bonuses to employees (see contra)		22,270.15
General Fund Account, as annexed		518,970.36
		$581,974.27

NOTES TO BALANCE SHEET

Note A: As of August 31, 1940, the Foundation was obligated in the amount of $155,675.64 under a contract relating to construction of a laboratory building in Newark, Delaware, on account of which payments aggregating $49,755 had been made at that date. Additional amounts payable under the contract at August 31, 1940, for work completed aggregated $37,119.75 of which amount payment of $9,187.48 will be withheld as a guarantee of satisfactory construction until completion of the building.

Note B: No provision has been made for amortization of improvements having a cost of $11,461.75, made to property vacated during December, 1940. Of these improvements, some portion, not determinable as of August 31, 1940, may be salvaged for use in the laboratory building under construction at that date.

STATEMENT OF GENERAL FUND ACCOUNT
for the fiscal year ended August 31, 1940.

Balance, September 1, 1939		$412,695.95
Add:		
Appraised value of 60 shares Christiana Securities Company common stock, received as donation for general purposes	$162,000.00	
Proceeds of sale of 20 shares Christiana Securities Company common stock, received as donation toward cost of laboratory building	65,624.00	
Interest received on special time deposit account created to provide funds for payment of cost of laboratory building	430.43	
Nominal value assigned to land at Newark, Delaware, donated as site for laboratory building	1.00	
		228,055.43
		$640,751.38
Less, excess of expenses over income available for purposes of the Foundation for the year ended August 31, 1940, as annexed		121,781.02
Balance, August 31, 1940		$518,970.36

STATEMENT OF EXPENSES AND INCOME
for the fiscal year ended August 31, 1940.

Expenses.

	Salaries and Wages.	Other.	
Building operation and maintenance		$11,975.82*	
Administrative and general	$26,867.44	2,101.39	
Laboratory	89,670.36	9,461.08	
Publications and printing		699.58	
Dues and subscriptions		641.81	
Traveling and entertainment		1,335.69	
Administrative charge, The Franklin Institute		5,000.00	
Moving expenses		2,603.03	
Miscellaneous		124.88	
	$116,537.80	$33,943.28	$150,481.08

Income.

Donation	$2,500.00	
Income received from investments, Emma M. Schaible Bequest	182.00	
Royalties received on sales of book, "Cancer and Diet"	12.08	
	$2,694.08	
Other income:		
Profits on sales of investments	26,005.98	
		28,700.06
Excess of expenses over income for the period, transferred to General Fund account		$121,781.02

* Includes provision of $436.80 for amortization of improvements to leased property.

NOTES FROM THE BARTOL RESEARCH FOUNDATION.

FAST NEUTRONS AND PARTICLES WITH HIGH SPECIFIC IONIZATION IN THE COSMIC RADIATION AT HIGH ELEVATIONS.*

BY

S. A. KORFF.

In a series of flights the number of particles producing large amounts of ionization was measured in the stratosphere with proportional counters. The counters were so adjusted that they did not record pulses produced by ordinary beta- or gamma-rays, but only those produced by particles possessing more than an assignable minimum of specific ionization. In two flights, boron trifluoride counters were used and in two others, different gases were employed.

A proportional counter, filled with boron trifluoride, and adjusted not to detect electrons, will count, in the stratosphere, at a rate equal to the sum of three quantities, A, B and C. A is the number of slow-neutron-induced boron disintegrations, the resulting alpha-particles being counted. B is the number of recoil nuclei produced by fast neutrons traversing the counter, and C is the current of other particles of high specific ionization passing through the counter. In this case it is evident that:

$$A = VN_B\rho\sigma_c v_c,$$

$$B = VN\int_{v_2}^{v_1} i(v)\sigma(v)dv, \qquad C = S\int_{v_4}^{v_3} I(v)dv, \qquad (1)$$

where V is the volume of the counter, N_B the number of B^{10} nuclei per cc, ρ the density of neutrons per cc with energies in the $1/v$ region, σ_c the capture cross section for B^{10} for neutrons of velocity v_c, N the total number of nuclei per cc in the counter, $i(v)dv$ the current of fast neutrons of velocity between v and $v + dv$, σ the recoil cross section of the nuclei of the gas used for neutrons of velocity v, S the cross-sectional area of

* Reprinted from *The Physical Review*, **59**, 214 (1941).

the counter and I the current per cm², of particles of high specific ionization. The limits of integration, v_1 is the highest and v_2 the lowest neutron velocity producing measurable recoils; v_3 the highest and v_4 the lowest velocity of a particle traversing the counter and producing enough ions to record as a count.

The factor A will be zero for counters using gas other than BF_3. Factor B is proportional to the number of nuclei in the counter (pressure times volume), while C depends on the cross-sectional area of the counter. Hence the use of counters of different sizes and pressures will permit a separation of the effects. Inserting in Eq. (1) the observed counting rates on the four flights, the known S, V and N, taking $(\sigma_c v_c)$ as 10^{-16} and σ as 10^{-24}, we obtain values for ρ, i and I. These are, respectively, at 2 meters of water equivalent below the top of the atmosphere: $\rho = 1 \pm 1 \times 10^{-6}$ per cc; $i = 5 \pm 2$ per cm² and $I = 1.4 \pm 0.7 \times 10^{-3}$. These values of ρ and i are in substantial agreement with those previously established by ourselves [1] and others,[2] while no previous measurements exist for I. It is quite impossible to account for the observed results on the basis of fast neutrons alone, by assuming that C is zero, unless the fast neutron flux be supposed increased by a factor of several hundred.

It was necessary to show that gamma-rays had no influence on the counting rate. Before each flight the counter was tested with and without a quantity of radium nearby, which produced in the counter an amount of ionization between 2 and 5 times that encountered in the stratosphere. The backgrounds were thus determined, as was the counting rate in the presence of a known flux of neutrons, with and without the additional gamma-rays.

It seems improbable that large showers could account for the results since (a) it would require over 200 electrons passing simultaneously through the counter to make it discharge, and (b) there was no shower-producing material nearby, the batteries being far below and only the thin glass wall and cardboard container above.

[1] H. A. Bethe, S. A. Korff and G. Placzek, *Phys. Rev.* **57**, 573 (1940).

[2] H. v. Halban, L. Kowarski and M. Magat, *Comptes rendus*, **208**, 572 (1939).

Further tests were made by operating the counter at two voltages during a flight, each voltage being maintained constant for 3 minutes. This, in effect, may be considered as varying the lower limit of the integral in B and C by known amounts. The counting rate could be compared with the previously calibrated rates when the same arrangement was operated in the presence of a known neutron source.

It seems necessary to conclude that fast neutrons alone cannot account for all the observed counts, but that a flux of fast particles of high specific ionization exists. These may be primary protons at the ends of their ranges, or other nuclear particles produced by the radiation. Further details will be published shortly.

Acknowledgment for support is made to the Carnegie Institution of Washington.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Seminar on the Electron Microscope.—DR. STUART MUDD, of the Department of Bacteriology of the University of Pennsylvania, gave an informal talk on the Electron Microscope before the seminar group of the Biochemical Research Foundation and guests on January 31, 1941.

Dr. Mudd prefaced his talk by referring in no uncertain terms to the New York newspaper which had "interpreted" his New York lecture for him, writing glibly of waving tentacles and liquid muscles in connection with his statements and photographs of bacterial flagella.

A brief history was given of the electron microscope covering its theoretical basis and technical development in Copenhagen, in Germany, and in Brussels, and finally at the R. C. A. Manufacturing Company. The activities of Dr. Marton, of Brussels, now a consultant with R. C. A., and Dr. Zworykin and Mr. Hillier, of R. C. A., were cited as the stimulus for the development of the present instrument.

The R. C. A. electron microscope is the first instrument of its kind to be produced on a commercial scale in this country and it is expected that a dozen or fifteen will be available (for wide distribution) before long.

The theory and value of the microscope was discussed in some detail by the speaker but particular stress was laid on the fact that the present instrument is only a beginning and is now roughly at the stage of development at which Gallileo found the compound microscope.

After comparing the light path of the ordinary microscope with the electron path of the electron microscope, Dr. Mudd discussed the field of application of the instrument. The resolving power of the new instrument was stated to be its chief point of advantage in that it works in a range previously closed to investigators. The light microscope resolves to 0.2μ or 2,000 A° while the ultraviolet microscope under the

best conditions resolves to 0.1μ or 1,000 A°. The electron microscope is capable of resolving particles between 1,000 A° and 50 A° with a maximum operating efficiency at present around 100 A°. Since X-ray diffraction methods resolve up to 100 A° the new microscope covers this unexplored region. Dr. Mudd drew attention to the fact that many medical and biological materials lie in this range between 100 A° and 1,000 A°, making this unknown gap all the more important.

The speaker did not hesitate to point out the present limitations of the instrument, mentioning in particular that it was necessary to use extremely thin films for study and that the samples had to be placed in a very high vacuum. These limitations prevent the use of the instrument for tissue slides or plant cells and will continue to do so until greater penetrating power of the electrons is obtained and a method of mounting can be found which will not give rise to artifacts. It is not possible to use a glass slide as a mount, so thin collodion films are made by floating nitrocellulose on water and lifting the film out with a fine copper wire screen. The objects are either dusted on the film or placed on in water and dried.

Another factor of uncertain advantage lies in the great depth of focus of the electron microscope. Depth of focus is often greatly desired with the light microscope but with the electron microscope it is so great that differentiation of the top, bottom and inner portions of the object is often difficult.

Before showing his slides, Dr. Mudd told of the air of bewilderment shown by some of the medical guests attending the meeting of the American Institute of Electrical Engineers in Philadelphia and the opinion of a few that the new instrument was just another gadget. He said he himself had felt like Alice in Wonderland at first but was now coming to the full realization that research programs could be developed for study of many perplexing problems now confronting us, particularly in the fields of bacteriology and virus study.

The speaker illustrated his talk with 22 excellent lantern slides of various bacterial and virus preparations. Among the many interesting things shown were the mucoid coating around streptococci, the continuity of surface membrane between the bacteria in chains and the pinching-off effect along

the chain at several points. Plasmolysis of certain of these organisms was also shown clearly and it was possible to see the solid cell membrane enclosing a shrunken area of protoplasm. Ghost cells could easily be seen after treatment of streptococci with the sonic vibrator.

Metachromatic granules could plainly be seen in slides showing diphtheria and tubercle bacilli and a curious string of small granules surrounding these latter organisms seemed to the speaker to offer interesting points for study.

The flagella of Eb. typhi were plainly shown and appeared to be tubular or double. Recent work by Pijper, of South Africa, using heliostat light, was stated by the speaker to have indicated that these flagella were in the form of spirals which lengthened and shortened along their principal axis to propel the organism. This type of problem should also make a good research study for the electron microscope.

Slides were shown of spores of B. subtilis and intact and cytolyzed vegetative cells.

Very interesting pictures of virus preparations drew especially close attention from the seminar group. These included pictures of dried preparations of dense suspensions of tobacco mosaic nucleoprotein which appeared as individual molecules (known to be of 40–60 million molecular weight). The aggregation and breaking off of the molecules could be noted and the side-by-side arrangement was often visible. Cucumber mosaic virus was seen as more slender molecules and the infectious material of equine encephalomyelitis was clearly visible in other slides.

Dr. Mudd brought out the interesting fundamental fact that direct measurements of these virus molecules showed close agreement with the values found by the complex indirect physical measurements of molecular dimensions as shown by studies with the ultracentrifuge, diffusion and double refraction of flow.

The seminar closed with the answering of numerous questions asked by the members of the group and with hearty applause for the speaker for his fine presentation of the story of this new tool of science and its uses.

Seminar on " Dissociation Constants and other Properties of Simple Amino Acids."—DR. SAMUEL GLASSTONE, of the Frick Chemical Laboratory, Princeton University, spoke to

the Foundation's Seminar group on certain properties of amino acids on March 14, 1941. After briefly reviewing the problem of the dissociation of acids and bases in general, the speaker pointed out that for a diprotic acid the ratio of K_1/K_2 (K_1 and K_2 being the dissociation constants for the first and second dissociations respectively) is a measure of the difficulty experienced by the proton of the second dissociation stage in leaving a negatively charged ion. With increasing distance between the acidic groups the retarding effect becomes smaller and, for dicarboxylic acids, the magnitude of K_1/K_2 falls from a value of several hundred thousand to a theoretical value of 4, decreasing asymptotically because of the inverse square law.

Glycine, $NH_2 \cdot CH_2 \cdot COOH$, was introduced as an example of an amino acid and it was pointed out that the older theory postulated the equilibria:

$$^{+}NH_3 \cdot CH_2 \cdot COOH \underset{\text{alkali}}{\overset{\text{acid}}{\rightleftharpoons}} \underset{\text{neutral form}}{NH_2 \cdot CH_2 \cdot COOH} \underset{\text{acid}}{\overset{\text{alkali}}{\rightleftharpoons}} NH_2 \cdot CH_2 \cdot COO^{-},$$

while the modern theory, based on Bjerrum's dipolar-ion theory, visualizes the equilibria:

$$^{+}NH_3 \cdot CH_2 \cdot COOH \underset{\text{alkali}}{\overset{\text{acid}}{\rightleftharpoons}} {}^{+}NH_3 \cdot CH_2 \cdot COO^{-} \underset{\text{acid}}{\overset{\text{alkali}}{\rightleftharpoons}} NH_2 \cdot CH_2 \cdot COO^{-}.$$

The evidence in favor of the modern view was concisely summarized, and attention was drawn to the fact that when formalin is added to glycine solution the titration of the glycine with alkali is changed; since the formalin reacts with the NH_2 group, the alkali must react with the $^{+}NH_3$ group (a relatively weak acid) in the absence of formalin. The fact that the titration with acid is not affected by formalin implies that acid titration neutralizes the COO^{-} group (a relatively weak base) of the neutral amino acid. It is therefore convenient to treat $^{+}NH_3 \cdot CH_2 \cdot COOH$ as a diprotic acid, the COOH group being fairly strongly acidic and the $^{+}NH_3$ group being fairly weak. As with other diprotic acids this will have two dissociation reactions, viz., that of carboxylic acid:

$$^{+}NH_3 \cdot CH_2 \cdot COOH + H_2O \rightleftharpoons {}^{+}NH_3 \cdot CH_2 \cdot COO^{-} + H_3O^{+},$$

$$K_1 = \frac{[^{+}NH_3 \cdot CH_2 \cdot COO^{-}][H_3O^{+}]}{[^{+}NH_3 \cdot CH_2 \cdot COOH]},$$

and that of the ammonium ion acid:

$$^{+}NH_3 \cdot CH_2 \cdot COO^- + H_2O \rightleftharpoons NH_2 \cdot CH_2 \cdot COO^- + H_3O^+,$$

$$K_2 = \frac{[NH_2 \cdot CH_2 \cdot COO^-][H_3O^+]}{[^{+}NH_3 \cdot CH_2 \cdot COO^-]}.$$

Since the ease with which the proton separates from the $^{+}NH_3$ group will be related to the nearness of the negative COO^- group, the value of K_2 and, therefore, of the ratio K_1/K_2 will depend upon the distance between the $^{+}NH_3$ and COO^- groups.

Dr. Glasstone then proceeded to give an account of his own work on the dissociation constants of the series of peptides containing from one to seven glycine residues. The determinations of K_1 and K_2 were carried out in the conventional manner from the neutralization curves, the pH measurements being made by means of a glass electrode. The results showed that the value of log K_1/K_2 decreased from 7.47 for glycine to 5.04 for diglycine, in agreement with expectation since the acidic groups are further apart in the diglycine. Further increase in distance produced relatively little change in ratio of K_1 to K_2 up to and including pentaglycine, but the value for hexaglycine showed a significant drop to 4.56, rising again slightly to 4.75 for heptaglycine. The value of K_1, from diglycine onwards, remained substantially the same for the various members of the series, the decrease in the value of log K_1/K_2 being due to increase in the value of K_2.

The dissociation constant of an acid or base is related to the decrease of free energy of the dissociation process, and hence it is possible for the value of the dissociation constant to change as the result of marked entropy change. If the process $^{+}NH_3 \cdot R \cdot COO^- + H_2O \rightleftharpoons NH_2 \cdot R \cdot COO^- + H_3O^+$ is accompanied by a structural change leading to an increase of entropy, e.g., if the dual ion $^{+}NH_3 \cdot R \cdot COO^-$ has a restricted structure whereas that of the negative ion $NH_2 \cdot R \cdot COO^-$ is free, the dissociation constant of the ammonium ion acid will be greater than it would be if the two forms had the same configuration. A possible interpretation of the results described is, therefore, that in the first five members of the glycine series, $^{+}NH_3 \cdot R \cdot COO^-$ and $NH_2 \cdot R \cdot COO^-$ have the same unrestricted structure, but in hexaglycine there is a change such that the negative ion has the same configuration as previous

members of the series whereas the configuration of the dual ion has become restricted. The same structural change in the $^{+}NH_3 \cdot R \cdot COO^{-}$ ion is presumably maintained in the heptaglycine.

Some confirmation of this suggestion was shown to be provided by data already available in the literature on the dielectric increments for a series of polyglycines in aqueous solutions. Here again after a regular change in dielectric increment over the lower members of the series (suggesting relatively free movement within the molecule of amino acid in spite of the electrostatic attraction between the end groups) there is a marked break (decrease) in the dielectric increment between penta- and hexaglycine; the low value at this point in the series implies a shorter distance between the charged end groups than would hold if there were free movement. Hence it appears that when the molecule contains six glycine units there is some modification of the structure of the dual ion which makes free movement more difficult.

Dr. Glasstone concluded his remarks by discussing an effect which had been revealed during the preparation of polyglycine esters in connection with dissociation constant measurements. This effect was the splitting of the esters by hot alcohol in the presence of hydrochloric acid, and it was studied by determining the specific reaction rates for the alcoholysis of the ethyl esters of the polyglycine series. Since water slows down the splitting of the glycine chains it is probable that the reaction is a true alcoholysis catalyzed by the ethoxonium ion $EtOH_2^{+}$. The reaction probably takes place as depicted below, e.g., for the diglycine ester:

$$^{+}NH_3 \cdot R \cdot CO\overset{(1)}{\text{—}}NH \cdot R \cdot CO_2Et$$
$$EtO\text{—}H$$

the product being two molecules of glycine ethyl ester. For the triglycine ester, the splitting can occur in two positions, indicated by 1 and 2, thus

$$^{+}NH_3 \cdot R \cdot CO\overset{(1)}{\text{—}}NH \cdot R \cdot CO\overset{(2)}{\text{—}}NH \cdot R \cdot CO_2Et$$
$$EtO\text{—}H \qquad EtO\text{—}H$$

the product being one molecule of glycine ester and one of diglycine ester in each instance. The latter subsequently undergoes further alcoholysis as indicated above. With tetraglycine ester two types of splitting are possible, one yielding two molecules of diglycine ester and the other a molecule each of glycine and triglycine ester. From an analysis of the experimental results of the rates of hydrolysis, treating the process as one involving a series of consecutive first-order reactions, it appeared probable that the latter process predominated. By making the assumption that the alcoholysis of penta- and hexaglycines involved a similar reaction, namely the splitting off of one of the end molecules of glycine as the first stage, it was found possible to derive the specific reaction rates in each case. The results showed an increase in the rate of alcoholysis from di- to triglycine ester; the rates of the first stage of alcoholysis of tri-, tetra- and pentaglycine esters then remained almost constant. With the hexaglycine ester, however, a marked increase in the reaction rate occurred.

The increase observed in the alcoholysis rate constant from the diglycine ester to the triglycine ester is to be expected since the smaller repulsion of the positively charged catalyst-ion at the second peptide linkage will result in a higher reaction rate. Further, the approximate constancy of the reaction rates for the tri-, tetra- and pentaglycine esters shows that the interior linkages are not easily broken and that the center linkages do not become weaker with increasing chain length. The sudden increase in the reaction rate for the hexaglycine ester suggests, again, a structural change in passing from the penta- to the hexaglycine chain.

Summarizing, Dr. Glasstone said that all the evidence favored the conclusion that, in the simpler polyglycines, structural changes occur between the penta- and the hexaglycine molecules. With the free acids this change appeared to be a restriction of free movement in the $^{+}NH_3 \cdot R \cdot COO^{-}$ form in the higher members, but with the esters there did not appear to be any evidence as to the nature of the structural change.

(Reported by EDWARD B. SANIGAR.)

BOOK REVIEWS.

SCATTERING OF LIGHT AND THE RAMAN EFFECT, by S. Bhagavantam. 333 pages, illustrations, 19 × 26 cms. Waltair, Andhra University.

The foreword of this book is written by Sir C. V. Raman who states that the author has been the most assiduous investigator in this field of physics in India during the past ten years. Further, the author has made many significant contributions to the subject, the value of which have been widely recognized. With this statement, the book certainly deserves more than usual attention.

This book is illustrative of the now well established procedure and place of the different types of scientific literature. Origins of subjects and fields of investigation make their appearance in periodical and society literature scattered with respect to locations and subject of pertinent interest. This continues until growth has resulted when it is necessary to gather together the literature and present a connected account of the theories and experimental facts for the furtherance of progress. This book finds its place here.

The early chapters of the book contain an account of the scattering of light in so far as it relates to that branch which may be called the Rayleigh scattering. This is approached through a discussion on the reflection and refraction of light, diffusion, and the color of the sky, ocean and of ice. The laws of the scattering of light are given treatment and experimental results covered. No change of wave-length is contemplated to this point. Chapter X on the principal experimental results in Raman effect begins what may be termed the second part of this book, revealing the significance of the new radiations discovered by Raman in 1928. A brief story of the main events which led up to this discovery is related and the results obtained by many investigators are outlined and discussed in the succeeding chapters. First the theory of Raman scattering is laid down. Then there is covered the Raman effect and molecular structure, relation to crystal structure, to inorganic chemistry, to physical chemistry, and to organic chemistry.

The subject requires a very broad coverage and this book does it justice. Of no little importance in accomplishing this is the simpleness of language used and the directness of presentation. Indeed, this is a feature not to be overlooked, for it also makes impressionable reading. The book is a valuable tool for the furtherance of knowledge and the obtaining of results in this field of research.

R. H. OPPERMANN.

FOUNDATIONS OF MODERN PHYSICS, by Thomas B. Brown. 333 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1940. Price $3.25.

The term "modern physics" is used a great deal these days. It covers a lot of ground and holds much promise, as is evident from what has already been accomplished of a practical nature. Roughly speaking, modern physics is concerned with three major questions: (1) What is the nature of matter? (2) What is the nature of "light"? (3) What is the nature of electricity? Scientific investigation has revealed that these questions are not independent or separate, that they

are interrelated, and therefore not capable of independent answers. While much work has been done along these lines, the continued opening of new avenues of research, provide a wide unexplored field.

This book is the outgrowth from teaching a course at George Washington University by the author. It includes coverage of those older parts of physics which are necessary to the understanding of the modern physics, as well as the more important and more fundamental of the practical applications which have followed discoveries whose primary importance is to science itself. There are eighteen chapters to the book. The arrangement and sequence shows an unusual acquaintance with this many sided subject and its presentation to students. At the outset the elementary electric charge and the electron is discussed with stress being laid on vacuum and gaseous tubes. From here the student is led through topics on dimensions of atoms, the wave character of light and polarized light, establishing ample evidence for the existence of light waves and also that they are transverse waves. The medium in which they travel and the identity of their vibrations are next examined in another field of physics, the field of electricity and magnetism. Electrical oscillation and electromagnetic waves are studied followed by the electromagnetic spectrum from the infra-red through x-rays. The photo-electric effect, a phenomenon which cannot be satisfactorily explained by light waves is inserted here.

Consideration of the atom, a loose end from the early part of the book is again taken up, using the background of the nature of light now established. This comes under the topic, the hydrogen spectrum and the hydrogen atom followed by a treatment on optical spectra and atomic structure and x-ray spectra. The kinetic theory of matter is then reviewed, under molecular motions, to facilitate understanding of the latest developments. Crystals, black body radiation, radioactivity, nuclear structure and theory, and cosmic rays are subsequent chapters in the book.

The book, being more of an introductory nature, avoids to a considerable extent technical terms and phraseology except where explanations aregiven. In this sense the treatment lays between a highly theoretical treatise and a popular work of explanation. Only elementary mathematics is used. In spite of this the book is remarkable in the careful interpretations of the mathematical processes involved. The nature of the book also allows for the free play of interest creating and sustaining material in the way of descriptions and explanations of practical applications of which the author has taken full advantage. At the end of each chapter there is a list of problems for exercise, references for additional reading and for advanced reading. Students of physics will find in this book a great assistance to obtain acquaintance with modern physics.

R. H. OPPERMANN.

A TREATISE ON ADVANCED CALCULUS, by Philip Franklin. 595 pages, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1940. Price $6.00.

Calculus is not the mystery that it used to be. Thanks to the progressive methods of teaching, acquaintance with the subject is widespread with the consequent benefit of its application in science and engineering. Of no little importance to the development of methods of presentation to students is the "follow through," i.e., a logical treatment after the study and acquisition of technique.

The author addresses this book to this purpose and as such it represents a means for acquiring a knowledge which should supplement and strengthen that of technique of the calculus.

The treatment here does not have distinct borders or limitations. Rather is it a gradual slope of preliminaries leading up to the subject, which has the double benefit of orienting the student and providing a proper background. Thus, the book begins with the real number system wherein there is sketched a method of starting with positive integers and logically developing the complete system of positive and negative, rational and irrational numbers. There is discussed the concept of functional dependence of one real variable upon another, developing certain results on the approach of a variable to a limit which are related to the notion of continuous function. From this study is made of certain consequences of the property of continuity. The third chapter is entitled exponential, logarithmic, and trigonometric functions. With regard to trigonometric functions the author states "the arithmetic definition given here is believed to be new in detail although in principle it goes back to Ptolemy. Unlike definitions based on integrals or series, it avoids giving the student the impression that trigonometry is dependent on integration or function theory."

With these preliminaries, the study of the special limit process, differentiation, is entered. There are outlined the fundamental theorems on differentiation, the mean value theorem, and various theorems about derivatives and applications of differentiation related to it. Complex numbers are defined and the four fundamental operations for them. Concepts of function, limit, and continuity are enlarged upon so that they apply when the variables are complex, and then a definition is given of the basic elementary functions for complex values of the independent variable. Proof is made of the fundamental theorem of algebra and this is applied to the decomposition of polynomials and rational functions.

Integrations is given a well rounded treatment. Brought out in the investigation of some of the properties of integrals in that under certain conditions integration and differentiation are inverse operations. The discussion of the Riemann integration of bounded functions includes Lebesgue's condition, as well as those of Darboux and Jordan. With a view to physical applications, a simple type of Stieltjes integral, is discussed. The discussion of the theory of functions, Fourier series and Fourier and Laplace transforms is facilitated by a preliminary chapter on uniformity and other conditions for the inversion of limit processes. A special chapter is devoted to the Gamma function where many asymtotic expansions are developed, including that of Stirling.

The work is excellently done and of necessity contains a large number of excercises. The teacher will find it flexible enough to mold into courses of instruction and the student will find it of great assistance in providing a perspective of the subject.

R. H. OPPERMANN.

PRINCIPLES OF ELECTRICAL ENGINEERING, by William H. Timbie and Vannevar Bush. Third Edition completely rewritten, 540 pages, illustrations, 15 × 23 cms. New York, John Wiley & Sons, Inc., 1940. Price $4.50.

Like other well established branches of engineering, progress has resulted in an ever widening of the boundaries of electrical engineering. Starting with its

foundations of physics, new conceptions have arrived and from these, new ideas and practical applications have found their way into the design and operation of apparatus, equipment and machinery. If an electrical engineer of only fifteen years ago were suddenly transferred to similar environs today, he would find much that would bewilder him and there would be an urgent necessity for study to catch up.

The previous editions of this book are well known to a great many electrical as well at other engineers for they have had much use as a text and reference. The authors have now decided on a third edition for a two fold purpose—to keep abrest of the advances in theory and practice, and also the advances in teaching methods. The tenor of this third edition is similar to the two preceeding it and the book fits in a comparable place in a course of study. Prerequisites are a good course in college physics and a knowledge of geometry, trigonometry and the calculus.

The book starts by giving some fundamental considerations leading to a discussion of Kirchoff's Laws, currents and potential differences. A practical explanation of electric power and energy leads into methods of making short-cuts in the solution of network problems. The magnetic circuit and electromagnetism receive considerable space as do induced and generated electromotive forces and electric fields. The subject of electronics is introduced in the latter part of the book. No attempt is made to cover this as regard to vacuum tubes and their circuits to any degree of entirety but there is quite sufficient treatment to grasp some of the principles and build a foundation upon which further study may be based. Electronics here is also used as a subject for the background of the study of conduction in solids and liquids of which a simplified qualitative discussion of present theory is presented. The last part of the book refers back to earlier parts discussing phenomena involving both electric and magnetic fields. The interlinking of electric and magnetic fields elaborates on this phenomena and additions are made so that radio waves and other similar waves are included as a part of the theory of electric and magnetic fields.

The method of presentation is one that provides encouragement to the student and the book is similar in this respect to the former editions in that the simpleness of language and sequence make it suitable for those who wish to add to or brush up on their knowledge at home.

R. H. OPPERMANN.

ELECTRICAL CIRCUITS AND MACHINERY, by Frederick W. Hehre and George T. Harness. Volume 1, Direct Currents. 513 pages illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1940. Price $4.50.

The importance of introductory and elementary courses in electrical engineering can hardly be overestimated. With wider applications and the appearance of newer types of apparatus and equipment to perform more efficiently, an ever increasing opportunity is presented to apply theory to practice. Engineers of other branches than electrical find a knowledge of the principles of electrical engineering to be a distinct asset, so common are its applications becoming. A textbook devoted to the fundamental phases of the subject must therefore receive careful weighing.

Electric Circuits and Machinery is a two volume set covering direct and al-

ternating currents. Volume I, which is the book at hand, is devoted mainly to direct currents. It fits into the educational picture just after a course in physics and mathematics including the calculus, although little calculus is used. Its nature is mainly descriptive. After a brief introduction dealing with the electron theory as regards the nature of an electric current, the subjects of electromagnetism, the electric circuit, and self and mutual induction are discussed. The functions, materials and construction of parts of a dynamo-electric machine are then described. This is followed by treatments on the characteristics of the various types of generators and motors, and the determination of the losses, efficiency and rating of them. A chapter is devoted to direct current measuring instruments, another to auxiliary apparatus used with direct-current machinery such as switches, fuses, circuit-breakers, regulators, etc. The subject of electronics, while not strictly in the realm of direct currents, is included in the book. It enlarges on the introductory chapter leading into the conduction of electricity through gases. The last chapter on batteries describes the different types of batteries, their capacity and characteristics.

The book is well illustrated with photographs and the many diagrams necessary to explanations of windings, etc. The student of electrical engineering will find here a text covering the elements of direct current power sufficient to serve as a foundation for future studies. It is admirably adapted to a course which is supplemented with laboratory work to the extent necessary for practical experience. The student of other branches of engineering will receive an adequate training on direct current power subjects by the use of this book. In this case the method of presentation is such that the practical sides of the subject are primary. The book also has possibilities for the electrician or master mechanic who desires to become more acquainted with the theory behind the operation of direct current machines.

R. H. OPPERMANN.

AN INTRODUCTION TO ABSTRACT ALGEBRA, by Cyrus Colton MacDuffee. 303 pages, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1940. Price $4.00.

No better description can be given of this subject and the purpose of this book than that given in the Preface by the author. "The phenomenal development in Algebra which has occurred in recent years has been largely the result of a changed point of view toward the subject, the displacement of formalism by generalization and abstraction. The maxim so often emphasized by the late E. H. Moore that the existence of parallel theories indicates an underlying unifying theory has been thoroughly vindicated in modern algebra. Number theory, group theory, and formal algebra have been unified and abstracted to produce what is now known as Abstract Algebra.

"But abstract theorems are empty words to those who are not familiar with the concrete facts which they generalize. One of the major probelms in teaching algebra, and one which must be fairly met, is to give the student a selected body of facts from number theory, group theory, etc., so that he will have the background to understand and appreciate the generalized results. Without this background the game of playing with postulates becomes absurd."

Accordingly the theory of numbers is first discussed covering Peano's postulates through primitive roots, indices, and quadratic residues. The group theory

is then taken up, leading to algebraic fields, integral algebraic domains, rings and fields, perfect fields, matrices, and linear associative algebras.

Prerequisite to the use of the book is a course in the theory of equations. The treatment follows a logical path from the simple to the more complex. The Kronecker program of developing all number systems from the rational integers is carried through. Designed as a text for graduate students the book has all of the qualities in content as well as method of presentation to bring the student successfully to the point of being able to read and understand the more advanced books and the literature of modern algebra.

R. H. OPPERMANN.

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